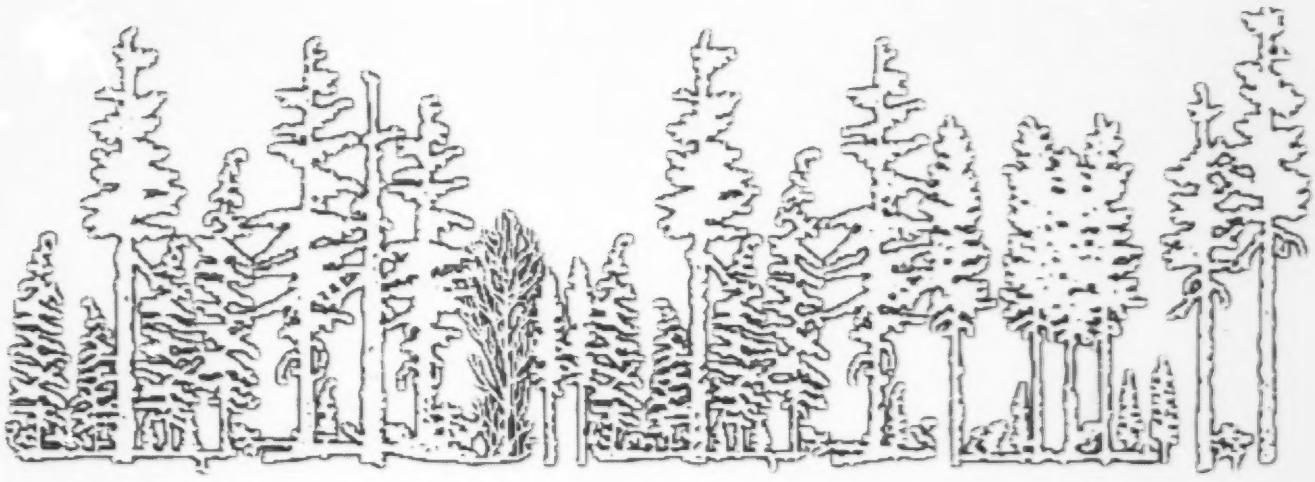
SILVICULTURE

Silvicultural Systems:

Their Role in British Columbia's Forest Management



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SILVICULTURAL SYSTEMS: Their Role in British Columbia's Forest Management

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FOREWORD

This document describes the major silvicultural systems used to manage forests and address the issues that relate to the application of these systems in British Columbia's forests. From this discussion a number of recommendations are made regarding ways to improve the information base and framework for silvicultural decision-making.

ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

The controversy surrounding the management of British Columbia's forests arises largely from a changing value system. While timber production has historically been the major management objective for B.C.'s commercial forests, forest management now includes non-timber objectives such as wildlife, fish habitat, recreation and water. More recently, aesthetics and biodiversity have been added to that list.

Silvicultural systems are a means of achieving management goals. Popular discussion regarding silvicultural systems in B.C. currently focuses on the pros and cons of clearcutting versus selection harvesting. The proponents of clearcutting cite cost-effectiveness, worker safety, ease of follow-up regeneration and stand tending activities among its advantages. Opponents of clearcutting cite the potential for site degradation and damage to non-timber values among its disadvantages. Similarly, the positive attributes of the selection system are cited as the maintenance of biodiversity and non-timber values. The negative aspects include increased risk to forest workers, cost of harvesting, regeneration and stand tending activities, and forest protection hazards.

The selection of silvicultural systems must be site-specific in consideration of management objectives, ecological and biological factors, operational considerations (such as safety, potential for damage to site) and socioeconomic factors. Within the context of a site's characteristics and resource values, forests can be managed for whatever goals society dictates — including timber production, wildlife, fisheries, water production, recreation, aesthetics and other values. The development and implementation of silvicultural systems in B.C. has historically focused on timber management objectives. Silvicultural systems must be selected, adapted and developed to achieve the new management objectives specified for forest management. In addition, considerable attention has now focused on "New Forestry", a management philosophy developed in the U.S. Pacific Northwest that seeks to maintain biodiversity.

To support this selection process, British Columbia must augment its current research program and undertake substantial field testing to develop comprehensive information on resource values and their interactions, the implications of different management systems on different forest types, and on the ability of different management systems to achieve timber and non-timber goals.

The processes of information transfer, training and decision-making must also be strengthened. Conflicting objectives must be reconciled and specific management goals must be identified at local, regional and provincial levels. Suitable management systems must be identified and/or developed to achieve these goals. The selection of forest management systems must incorporate timber and non-timber interests. Guidelines and training programs must be established to ensure safe and sensitive implementation.

Specific recommendations of this report include establishing:

- a program of research into the application of silvicultural systems in British Columbia;
- an extension and demonstration program to transfer research findings on the application and implementation of silvicultural systems and New Forestry in B.C. to professional, technical and forest worker audiences; and
- a communications program to inform the public about forest management practices and to clarify the concepts, application and implications of silvicultural systems.

INTRODUCTION

British Columbia's forests are part of every citizen's "backyard", valued not only for their commodities, but also for the experiences they provide, the flora and fauna they support and their part in the global ecosystem.

With this new perspective have come increasing demands. Provincial forests and forest lands must accommodate emerging needs for wilderness, recreation, research and development; conflicts are an inevitable part of the process of identifying priorities.

A major forest-related issue being debated in British Columbia at this time is the choice of the most appropriate silvicultural systems by which to harvest, regenerate and tend forest sites.

To address this question, the Ministry of Forests Silviculture Branch initiated a program in 1989 on silvicultural systems and undertook the study that is the subject of this report. The study had four objectives:

- to review the current status of silvicultural systems in British Columbia;
- to identify public and industry attitudes relating to forest management and silvicultural systems;
- to review the concepts of "New Forestry" and discuss the implications of its application in British Columbia; and
- to make recommendations on the development of silvicultural systems and forest management in British Columbia.

This report is organized into six major sections. First, a brief history of silviculture and forest management in British Columbia is provided, followed by an outline of the forest management controversy. Next, the variety of silvicultural systems available in B.C. are reviewed as to their characteristics, advantages and disadvantages. The considerations in choosing a silvicultural system are presented in the fourth section and include management goals, ecological and biological factors, and operational and socioeconomic considerations. In section five, New Forestry concepts are outlined and the challenges involved in applying the approach in B.C. are explored. Section six summarizes the issues pertaining to the selection and application of silvicultural systems. Section seven presents a number of recommendations for future research, training and communication to improve the information base and framework for silvicultural decision-making in British Columbia. References cited in the text are listed in the final section.

Specific detail is included in four brief appendices to the report. A glossary is provided as the first appendix. Appendix 2 consolidates the information on how silvicultural systems are used to serve forest protection objectives in some regions in British Columbia. Appendix 3 provides an overview of the silvicultural practices used in specific forest types in the United States.

A HISTORICAL PERSPECTIVE

Timber harvesting in British Columbia has evolved over a period slightly exceeding one hundred years or, in timber production terms, about one rotation.

During the first half-century, approximately one-quarter of the total area that has been logged to date was harvested. On the Coast, harvesting was done mainly as clearcutting. Logs were yarded to railroads by cable systems. Trees considered to be unmerchantable and other understory vegetation were left on-site as debris which, in many cases, hindered natural regeneration and posed a long-lasting fire hazard.

In the Interior, various logging methods, including selective harvesting,[1] were carried out by ground skidding and left a seemingly intact forest canopy. However, these methods were usually tantamount to "high grading," where only the most valuable trees were harvested, leaving a poorly spaced residual stand of inferior trees or undesirable species.

During this period, there is little evidence that the public was concerned about how its forest resource was being treated. Utilization was poor compared to today's practices, timber harvests were essentially unregulated, and holders of rights to Crown timber were free to harvest at whatever rate they chose. The forests of British Columbia were considered limitless, harvesting operations were remote, and the only pressure to encourage more responsible harvesting practices came from the technical staff of the Forests Branch (precursor to today's Forest Service) and from the larger forest companies.[2]

The legacy of this early period in B.C.'s harvesting history haunts the forest sector today. Many stands harvested by extensive, progressive clearcutting on the Coast and by high grading in the Interior have given way to economically undesirable crops. From a timber standpoint, some prime Coastal sites have been "lost" to non-commercial species such as red alder, vine maple, or brush, and some prime Interior wet-belt sites have reverted to lower quality stands. Without replanting, many Interior stands remain insufficiently restocked.

As public attitudes toward forest management evolved in the second half of the century, harvesting practices became more controlled. Amendments to the *Forest Act* in 1947 and 1948 implemented a policy of sustained yield for British Columbia forests. As part of that policy, forest regeneration by planting was begun on the Coast. Various guidelines and standards for harvesting, engineering and worker safety also began to evolve. During this period, the concept of forests as crops needing tending and protection developed.

In the Interior, at this time, the emphasis was on silvicultural systems that would make planting unnecessary after logging, either by protecting the understory and maintaining a healthy, well-spaced residual stand, or by leaving a viable seed source and seedbed after harvesting. Reforestation by planting became an option in the Interior in the 1960s, but natural regeneration remains in widespread use.

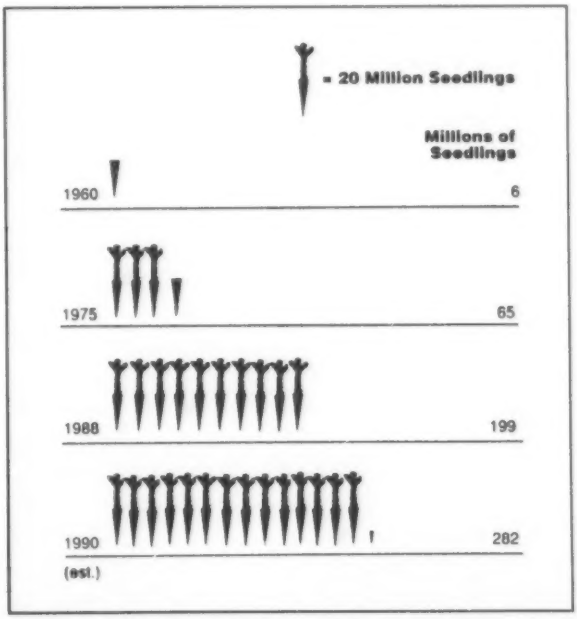

Figure 1. **Seedlings planted in B.C. since 1960. (From COFI, 1990)**

[1] Selective harvesting removes the highest quality stems from a stand (high grading); it is not to be confused with the selection silvicultural system which removes a mixture of stems to maintain an uneven-aged class structure.

[2] Knight, E. 1990. Reforestation in British Columbia: A Brief History.

In 1987, further changes in the *Forest Act* transferred the cost of establishing the next crop ("basic silviculture") to the holders of major forest harvesting licences. In addition, each licensee is now required to develop and submit a pre-harvest silviculture prescription (PHSP) for every harvesting site. The PHSP, a contract between the licensee and the Ministry of Forests, ensures that a free-growing crop of trees will be established after harvesting. This policy attempts to ensure that an effective silvicultural system is planned and implemented for each area logged.

Along with advancements in management systems and improved standards for timber harvesting, the latter half of this century has witnessed the recognition of non-timber resource values and the involvement of the public in forest planning. While the philosophy of forest management (and the policy framework for silviculture in B.C.) has continued to develop in accordance with public interests and concerns, knowledge of forest ecosystem dynamics and the effectiveness of various silvicultural practices has, in general, not kept pace.

The province's biogeoclimatic classification system provides a strong ecological framework for silvicultural decision-making, but the viability and efficiency of silvicultural systems other than clearcutting have not been systematically examined on each of the province's ecotypes.

As the 21st century approaches, the proportion of cut from second-growth stands will increase. By the nature of their location and infrastructure (e.g. developed road system, uniform tree size), these stands will offer greater opportunities to practice a variety of silvicultural systems. At the same time, hard choices about harvesting or preserving the remaining old-growth forests must be made. British Columbia's forest management goals must be re-evaluated in light of current issues, such as old-growth, biodiversity and ecosystem stability, and management systems must be developed to achieve these goals while continuing to produce timber and other forest goods.

THE FOREST MANAGEMENT CONTROVERSY

British Columbia is blessed with extensive forests whose benefits help to sustain the cultural, social and economic aspects of our B.C. lifestyle.

The demands on forests have grown as the population has increased and as the province has developed as a producer of high quality wood products and a tourist destination. Despite an abundance of forest land, some of British Columbia's forests are under extreme pressure — especially the old-growth stands that are so highly valued for the forest products, research opportunities and many experiences they offer.

Pressures on the forest land base come from many quarters. Tourism is the most rapidly growing sector of the B.C. economy as increasing numbers of Canadian and foreign visitors seek forested wilderness and other forest recreation experiences. International concern for the conservation of the planet's natural resources and the reduction of carbon dioxide and other emissions have intensified the public's anxieties about the harvesting of B.C.'s forests. There is growing public demand to preserve from harvest large areas of original forest for the study of natural ecosystems and the maintenance of biodiversity. At the same time, the health of the forest industry (and the B.C. economy) depends on sustained levels of harvest. In many locations this means a dependence on old-growth timber to bridge the transition to second-growth crops.

In addition to the inevitable conflicts that arise from the need to share a limited resource, there is also rising public dissatisfaction with the management of B.C.'s forests. The public accuses the Ministry of Forests, the forest industry and the forestry profession of overcutting the long-term sustainable harvest and environmentally degrading our forest lands. At a time when the forest sector is moving towards "forest farming" and becoming more efficient in the production of timber, the public is becoming increasingly discontent with what they perceive as a wholesale replacement of old-growth, naturally occurring forests by managed, single-species plantations.

Controversy surrounds the processes by which our forests are planned, managed, harvested and renewed. On one side, the "environmentalists" decry the prevalence of clearcutting, the timber production orientation of forest management and the lack of public involvement in forest planning. On the other, the "industry" defends the improvements it has made and laments what it perceives as a lack of public awareness of what constitutes ecologically sound, economically rational and operationally safe forest management and harvesting systems.

Two major issues lie at the heart of this controversy.

The issue that provides the focal point for current debate is the choice of appropriate silvicultural systems by which to harvest, regenerate and tend specific forest sites. In this arena, discussions of clearcutting and other silvicultural systems are pursued. The larger issue, in which the choice of silvicultural system is embedded, is the philosophy of forest management and the attendant issues of multiple use, ecosystem integrity, biological diversity and public involvement.

Clearcutting is the most common silvicultural system used in British Columbia today. While most agree that clearcuts are ugly, the forest industry argues that clearcutting is the least expensive of the alternatives, the safest method for forest workers and a system that does not permanently damage the ecology of the harvesting site. Environmentalists, on the other hand, argue that the environmental damage is extensive and that other silvicultural systems, such as selection cutting and shelterwoods, are less disruptive to the ecology of the site. The resolution of this debate cannot be made at a policy level, but requires site-specific consideration. Alternative systems must be field-tested across the variety of sites in British Columbia to determine their efficacy for meeting both timber and non-timber management goals.

Resolving the philosophical issue of forest management will also require careful consideration and field testing. The recent development of "New Forestry" in the old-growth Douglas-fir forests of the U.S. Pacific Northwest has precipitated strong public interest in the management of forests in a manner consistent with the development of natural forest ecosystems. The implications of such a philosophy are enormous for the B.C. forest sector and could

result in lower harvests, longer rotations and higher costs of almost all aspects of management and harvesting. The implications of not taking an ecosystem approach are equally staggering and could result in habitat fragmentation, loss of unknown ecosystem components, reduction in biodiversity and curtailment of future management options.

This is the crux of the forest management controversy in British Columbia: the notion of forest cultivation for the production of timber versus the maintenance and preservation of natural ecosystems. Associated with this issue is that of the appropriate silvicultural systems to achieve forest management goals.

This document does not attempt to resolve this controversy, but rather to clarify the debate by identifying the issues, describing the alternatives and discussing their implications.

SILVICULTURAL SYSTEMS IN BRITISH COLUMBIA

THE SILVICULTURE CONCEPT

Simply put, silviculture is the establishment (regeneration) and tending of forest crops. In British Columbia, the major silviculture treatments include: site preparation, planting, brushing, juvenile spacing and thinning.

These silviculture activities, combined with a method of harvesting to prescribe a long-term program of treatments by which a crop is tended, harvested and replaced, constitute a silvicultural system. The silvicultural system changes the structure and species composition of forest ecosystems. While it is primarily directed towards the regeneration of timber for wood products, it can also be used to meet the management objectives of other resources.

Silvicultural systems are named and classified according to the removal method of the mature crop. While public attention focuses on the harvesting operation, it is only one step in the system of forest cultivation. This section describes the four major silvicultural systems currently used in B.C.: clearcutting, seed tree, shelterwood and selection.

There are two basic classes of silvicultural systems: even-aged and uneven-aged management systems (Figure 1). Even-aged management creates stands in which the trees are the same age or in the same age class. Uneven-aged management creates stands in which three or more age classes are intermingled. Even-aged stands are maintained by the clearcutting, seed tree and some shelterwood systems; uneven-aged stands are maintained by the selection system (Table 2).

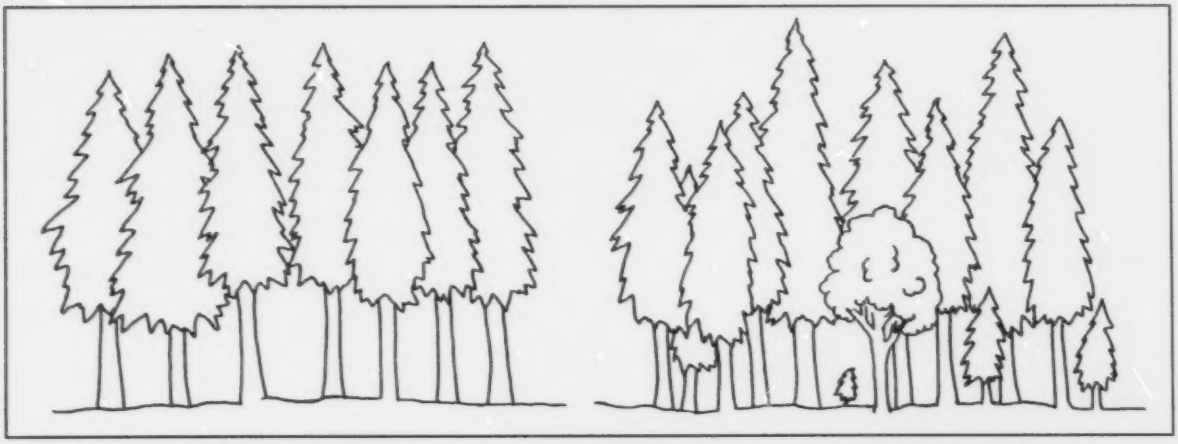

Figure 2. **Even-aged stands** **Uneven-aged stands.**

TABLE 1. A classification of silvicultural systems.

EVEN-AGED MANAGEMENT			UNEVEN-AGED MANAGEMENT
Clearcutting	**Seed Tree**	**Shelterwood**	**Selection**
Patch		Uniform	Single Tree
Progressive		Strip	Group
Strip		Group	

CLEARCUTTING SYSTEM

Clearcutting is the harvesting of all trees in an area in one cut to create a new, even-aged stand. The harvested patch is large enough to be mapped as a separate age class. Regeneration is achieved through natural seeding, sprouting of trees that occurred in the cut stand, and/or artificially through planting or direct seeding. The size and shape of cutblocks is influenced by environmental, economic and social factors (such as aesthetics), including the management objectives for non-timber resources and land uses. Factors such as soil stability, terrain, the existence of watercourses, and the potential for blowdown are major considerations in the location of cutblocks.

Advantages

- speeds removal of all trees and decreases economic losses where an outbreak of disease or infestation of insects occurs;
- allows the use of genetically improved species through planting;
- allows the regeneration to develop without being suppressed or damaged by a residual overstory;
- reduces the risk of blowdown in areas where shallow, cold and/or wet soils make trees vulnerable;
- suits natural regeneration of pioneer species (e.g. lodgepole pine, western larch);
- simplifies the logistics of harvesting, site preparation and other management practices with consequent economic efficiency;
- allows prompt reforestation and tending activities which reduce the time to the next harvest; and
- requires fewer roads and gives access to more volume per length of road than other systems.

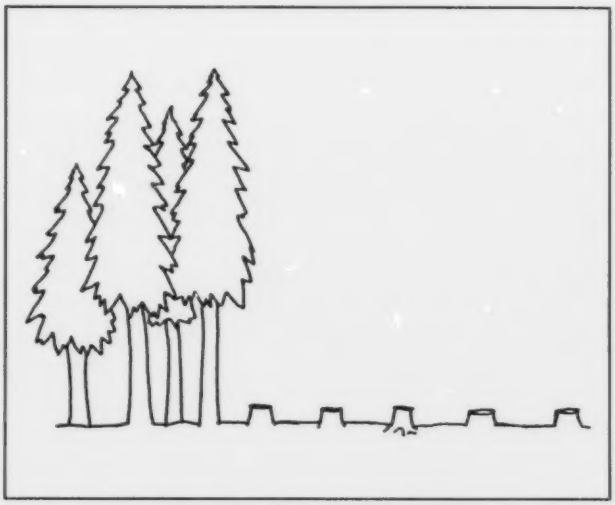

Figure 3. **Clearcutting System**

Disadvantages

- can increase mass wasting (e.g. slope failures) on steep slopes due to the loss of root strength and the reduction in transpiration associated with removing all trees;
- creates aesthetic concerns; in some cases these can be mitigated by landscaping of cutblocks;
- exposes the site to extremes of heat, frost, cold, wind and snow;
- eliminates thermal and protective cover for wildlife (generally 10-20 years);
- can expose streams critical for fisheries production and result in increased water temperatures, light penetration and algae growth, decreased litter inputs and degraded fish habitat;
- increases the potential for excessive surface disturbance and nutrient depletion of soil; and
- increases the potential for disease and insect attack because the regenerated trees are of the same age and development stage; this may be further aggravated when there is little or no mix of species.

Clearcutting is the most common form of industrial harvesting in British Columbia (Table 2); approximately 90% of the area harvested each year is carried out under this system. Clearcutting is the standard practice in stands of sun-loving species such as lodgepole pine and coastal Douglas-fir that have trouble regenerating in the shade of a full canopy of trees. It is suited to shallow-rooted species which are vulnerable to blowdown, and is also practiced as a means of stopping the spread of diseases, such as dwarf mistletoe.

SEED TREE SYSTEM

The seed tree system, a form of even-aged management, leaves selected standing trees scattered throughout the cutblock to provide seed sources for natural regeneration. Where feasible, the seed trees are harvested after regeneration is established. The seed tree system differs from the shelterwood system in that the seed trees offer little protection to natural regeneration. The number of seed trees to be left is a function of many factors, including the desired number of seedlings per hectare, the seed crop frequency, the seed dissemination distance and the length of time that the seedbed remains receptive.

Advantages

- provides more uniform seed dissemination for natural regeneration than clearcutting;
- provides better control of species composition for the future crop than selection systems;
- has lower logging costs relative to the selection and shelterwood systems, but higher than clearcutting;
- is more aesthetically appealing than clearcutting; and
- provides habitat for cavity- nesting birds in seed trees left through to the next rotation.

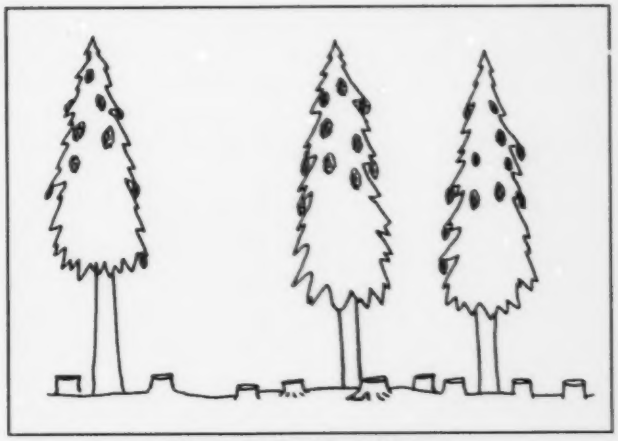

Figure 4. **Seed Tree System**

Disadvantages

- potential for windthrow of seed trees;
- lack of control of seedbed receptivity and competing vegetation;
- lack of control of spacing, timing and distribution of new crop;
- only suited to light-seeded species;
- rodents and birds eat much of the seed;
- the timber value of seed tree is foregone if not harvested;
- potential damage to regeneration if seed trees are harvested;
- lightning-prone sites must be avoided; and
- loss of genetic diversity.

As indicated in Table 2, the seed tree system is being implemented to some degree in the Cariboo, Kamloops, Nelson and Vancouver forest regions. In the dry Interior, the system is popular in mixed larch and Douglas-fir stands but has had sporadic success due to lack of seed crops and/or the quality of seed trees.

TABLE 2. Area (hectares) harvested by clearcut and selective* logging in B.C. 1988-89. (From 1988-89 Annual Report, Ministry of Forests)

REGION	CLEARCUT	SELECTIVE**	TOTAL
Prince George	65,718	17	65,735
Prince Rupert	33,338	100	33,438
Cariboo	49,389	5,858	55,247
Kamloops	30,496	7,219	37,715
Nelson	25,632	8,371	34,003
Vancouver	42,303	1,960	44,263
TOTAL:	246,876	23,525	270,401
Percent:	91%	9%	100%

* Includes silvicultural systems other than clearcutting.
** Some seed tree and shelterwood cutting is included in the Cariboo, Kamloops, Nelson and Vancouver Regions.

SHELTERWOOD SYSTEM

In the shelterwood system the mature stand is removed in a series of cuts. The first cuts create openings in the stand and regeneration occurs under the cover of a partial forest canopy or 'shelterwood'. Subsequent cuttings remove the shelter of the mature crop to make room for the new crop. A final harvest cut removes the shelterwood and allows the new stand to develop in the open as an even-aged stand. This system provides a continuous cover of trees on the site. It is especially adapted to species or sites where shelter is needed for the new seedlings, or where the shelterwood gives the desired regeneration an advantage over undesired competing vegetation.

The shelterwood method requires a minimum of two cuts — the seed cut to achieve regeneration of the new crop, and the removal cut to extract the remainder of the mature stems. The seed cut may be preceded by (or combined with) a preparatory cut which culls the stand of diseased, damaged, or undesirable trees.

The **preparatory cut** prepares the stand for reproduction. Trees are removed from the lower crown classes to create openings for sunlight. This speeds the decom-position of humus, encourages crown develop-ment and develops some wind-firmness in the crop trees.

The **seed cut** opens up the canopy to encourage regeneration of the desired species. This cut is timed for a year when seed of the desirable species is abundant. The trees removed are the least desirable intermediate and co-dominants; the number of residuals left is site- and species-specific. The residual trees add more diameter for the final harvest and produce more cones in the interim.

The **removal cut** consists of one or more harvests after the regeneration is established and needs more grow-ing space. The number of removal cuts is dependent on the regenera-tion's sensitivity to exposure (e.g. sun-scald, wind and storm damage).

The shelterwood system is practiced in different ways depending on the species, management goals and characteristics of the site. The **uniform shelterwood** method is carried out over an entire stand. The **strip shel-terwood** method is carried out in strips which are extended through the stand over time. The **group shelterwood** method is carried out in patches which are expanded throughout the stand over time. The shelterwood system

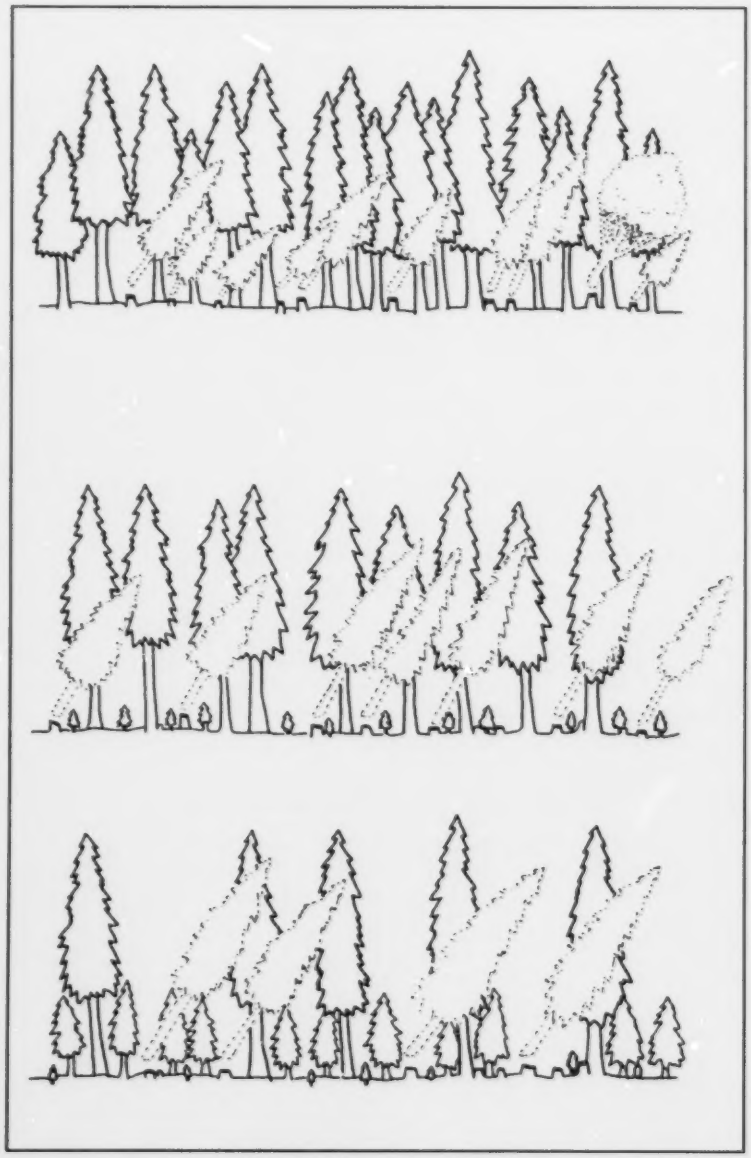

Figure 5. **Shelterwood System**

can also be practiced as an **irregular shelterwood** to produce an uneven-aged stand structure. There is one major difference between the selection system and the irregular shelterwood: the shelterwood has a final cut that removes all remaining mature stems, while the selection system keeps cutting mature trees in a continuous cycle.

Advantages

- provides less harsh site conditions than a clearcut (i.e. reduces extremes in temperature fluctuations, retains soil moisture and relieves moisture stress on new seedlings);
- can accommodate a diversity of tree species, ages and stand structures;
- slows the invasion of competing understory vegetation, thus leaving seedbeds receptive to tree seedling establishment for a longer time;
- is more aesthetically pleasing than clearcutting; and
- maintains thermal cover for wintering range of woodland caribou, moose, elk and deer.

Disadvantages

- not suited to species that are not windfirm or to sites with shallow soils;
- inappropriate with shade-intolerant species;
- potential for harvesting damage to the existing regeneration;
- potential for establishment of brush species due to light penetrating the canopy (depending upon the intensity of the preparatory and seed cuts);
- potential for insect and disease problems associated with an even-aged structure; and
- higher administration and logging costs than clearcutting.

The shelterwood system is being tested in a handful of research sites and demonstration forests in the B.C. Interior. It is used operationally in the Vernon Forest District, in community watersheds and on other lands where maintaining a forest cover is important to non-timber values, including aesthetics, wildlife habitat and pest management. Stands containing Douglas-fir, western larch and lodgepole pine are especially suited to shelterwood cutting.

The group shelterwood method is becoming popular in mixed coniferous types in the Vernon District. Small clearcut openings are created to remove 25-35% of the timber from a given area. The size of the cut area is limited to no more than three tree lengths. The shape of the opening varies in consideration of skid trail pattern, windthrow risk, minimization of cold air drainage and the proportion of diseased or insect-damaged trees. The advantages of this prescription over single tree selection and uniform shelterwood include greater operator safety for felling and skidding, easier slash disposal, reduced risk from spruce budworm to the understory and increased ability to control root rot centres.

SELECTION SYSTEM

The selection system creates or maintains uneven-aged stands in which trees of different ages and sizes intermingle singly or in groups. Under the selection system mature and immature trees are harvested either singly or in groups. Cuttings are made continuously so that regeneration is an ongoing process, seedlings never lose the protection of older age classes and a permanent forest cover is achieved.

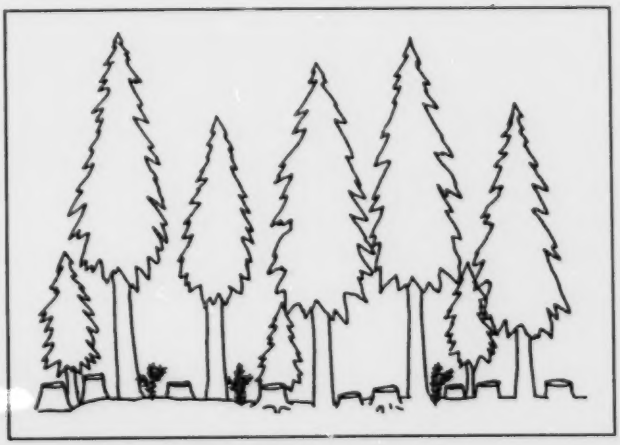

Figure 6. **Selection System**

Individual tree selection involves the removal of single trees from the stand. Trees are generally selected for their species, quality and size, with the objective of maintaining a variety of age classes and sizes. Trees not favoured for regeneration are also removed. In mixed species stands, this practice can increase the proportion of shade-tolerant species: insufficient light at the forest floor does not allow light-demanding species to germinate and grow.

Group selection can be used to maintain more of the light-demanding species by removing mature timber in clumps. For this purpose, larger harvest groups are more effective than smaller ones. In timber types where the stands are open or the trees are very tall, the groups may be as large as one hectare and resemble small clearcut patches. The group selection system differs from clearcutting since it creates a balance of age or size classes in a mosaic of small contiguous groups throughout the forest.

The choice of individual tree or group selection will depend on factors such as:

- the existing species;
- the desired tree species and their seedbed and growing requirements;
- the potential for wind damage of residual stems;
- the potential development of competitive species;
- the sensitivity of the soil to repeated entry;
- the topography, aspect, location of watercourses and potential for erosion; and
- the potential for spread of pathogens (e.g. dwarf mistletoe).

While the selection system is aesthetically pleasing, it is difficult to apply successfully in most forest types. To achieve a successful uneven-aged management system requires a great deal of planning and infrastructure (e.g. roads, skid trails), especially when both timber and other resource management goals are to be achieved. Timber production considerations, such as the desirable diameter distribution for the stand, the amount of residual growing stock left to accrue further volume, the maximum tree size that is attained before harvest and the interval between harvesting, must be integrated with the other resource management requirements. For instance: Will the uneven-aged management system retain or create suitable wildlife habitat (e.g. winter, spring or summer ranges)? Does the system include streamside areas and maintain stream integrity and fish production? How will wildlife and domestic animals affect natural regeneration? Will the system maintain recreation and aesthetic values?

Advantages

- maintains site stability by preserving continuous forest cover on-site;
- conserves aesthetic values;
- provides direct seed source and shelter for regeneration;
- discourages heavy brush competition;
- offers more flexibility for incorporation of non-timber values than clearcutting; and
- provides access (via road/trail network) for protection, silviculture treatments, recreation and other resource uses.

Disadvantages

- contributes to potential for damage to residual crop (root, bark, broken tops) during harvesting;
- increases potential for fire hazard due to heavy slash accumulations during harvesting;
- generates lower timber yields and values, and higher costs than even-aged management;
- can cause a species shift towards more shade-tolerant species;
- requires more extensive road network than clearcutting;
- can damage thin or sensitive soils by heavy or repeated traffic and can result in erosion or regeneration problems associated with compaction;

- requires more highly trained staff to manage and implement; and
- creates a time lag in securing natural regeneration due to sporadic frequency of seed crop.

The selection system is used in the Interior of British Columbia in mixed stands of Douglas-fir/larch/lodgepole pine to remove the pine and favour Douglas-fir and larch as the final crop. In second-growth stands it is being used to simulate old-growth winter range conditions for black-tailed deer. It is also being used in areas of the province affected by mountain pine beetle. By removing pines in mixed stands the regeneration of more vigorous and resistant species is encouraged. Many of the province's small-scale woodland operations located in second-growth stands where the timber is still capable of significant increases in volume and value are using the selection system with success. Selection cutting is the preferred system for harvesting special products, such as pilings, poles and building logs.

Research, demonstration and operational trials of selection systems have been carried out in each of B.C.'s six forest regions with the most extensive application in the Interior regions, as shown in Table 3.

TABLE 3. Location of selection system trials by Ministry of Forests region.

	VANCOUVER	PRINCE GEORGE	PRINCE RUPERT	CARIBOO	KAMLOOPS	NELSON
Research					•	•
Operational	•	•	•	•	•	•
Demonstration	•	•	•	•	•	•

Table 4 (overleaf) is a partial listing of the silvicultural systems, other than conventional clearcutting, which are being tested by the Ministry of Forests and forest companies in the various forest regions. Appendix 3 discusses the silvicultural systems being used in major forest types in the United States.

TABLE 4. A partial listing of silvicultural system monitoring programs in B.C. (other than conventional clearcutting).

LOCATION	SYSTEM	AFFILIATION
CARIBOO REGION		
Williams Lake	Non-clearcutting systems	- Weldwood, Ministry of Forests, and University of B.C.
KAMLOOPS REGION		
Clearwater	Selection Seed Tree	- Weyerhaeuser Canada and Ministry of Forests
Kamloops	Partial Cut Selection Small Clearcut	- Ministry of Forests
Lavington	Seed Tree Shelterwood Selection	- Tolko Industries
Merritt	Seed Tree Selection	- Ministry of Forests
Penticton	Seed Tree Partial Cut* Seed Tree Shelterwood Partial Cut	- Weyerhaeuser Canada - Ministry of Forests
Vernon	Seed Tree Shelterwood Group Shelterwood Selection (steep slope)	- Ministry of Forests
NELSON		
Cranbrook	Partial Cut	- Crestbrook Forest Industries
Slocan	Partial Cut (steep slope)	- Ministry of Forests and Slocan Forest Products
PRINCE GEORGE REGION		
McBride	Partial Cut	- Ministry of Forests
PRINCE RUPERT REGION		
Kispiox and Bulkley	Shelterwood Selection Small Clearcut	- Ministry of Forests
VANCOUVER REGION		
Boston Bar	Seed Tree Shelterwood Small Clearcut	- Ministry of Forests and Fletcher Challenge
Galiano Island	Selection	- MacMillan Bloedel private land

* refers to tree removal other than clearcutting where only part of the stand is removed.

CHOOSING A SILVICULTURAL SYSTEM

Choosing the right silvicultural system for a forest site requires consideration of the management goals for the site and various ecological, biological, operational and socioeconomic factors. The ideal silvicultural system will fulfill the management goals, subject to the biological realities and ecological limitations of the site and the socioeconomic requirements of the forest industry and forestry-dependent communities. In reality, choosing a silvicultural system requires trade-offs between these factors on a case-by-case basis.

MANAGEMENT GOALS

Management goals are usually expressed in terms of the production, protection, regeneration or enhancement of the resources desired on a particular site. These resources may include timber, range, recreation, wildlife, water and other values. A management goal may emphasize producing some mix of these resources, preserving biodiversity, or meeting aesthetic concerns about harvesting the site.

Some specific management goals which will influence the choice of a silvicultural system are:

- to ensure the efficient regeneration of commercially desirable stands of timber;
- to control damaging agents, such as erosion, pests and fire;
- to provide continuous habitat for cavity-nesting birds;
- to protect streambeds and spawning grounds;
- to retain old-growth stand characteristics;
- to protect recreational and aesthetic values;
- to maintain continuous habitat for specific wildlife species;
- to maintain biological diversity; and
- to maximize the economic returns from harvesting and silvicultural activities.

AN ECOLOGICAL FRAMEWORK

The overriding consideration in choosing a silvicultural system is that it be consistent with the ecology of the site. The silviculturist must have knowledge of the site ecotype, its natural processes of succession, and the site-specific ecological implications of each of the possible silvicultural systems. In British Columbia, a biogeoclimatic ecosystem classification is used to assess sites and evaluate the ecological implications of harvesting and other forest management practices. While the application of different silvicultural systems is carried out in some forest regions on an operational basis, more work is needed across the classification types to establish a broader information base for decision-making.

BIOLOGICAL FACTORS

The major biological factors influencing the choice of a silvicultural system are the establishment and growing requirements of the tree species (e.g. shade tolerance), the stand structure (e.g. even- or uneven-aged), climate, wildlife habitat requirements (e.g. shelter, food), climate and hazards of fire, insect and disease.

The silvics of tree species is among the most important factors influencing the choice of a silvicultural system, both in regard to the establishment of the crop and the subsequent vegetation management. For example, if shade-tolerant species, such as hemlock or western redcedar, are the desired regeneration, then the selection or shelterwood silvicultural systems might be the most appropriate. On the other hand, if sun-loving pioneer species, such as pine or Douglas-fir are desired, the clearcutting or seed tree systems are recommended. If forest regeneration must occur in the shade (as is often the case in the selection system), then shade-tolerant species will be selected naturally or as planting stock. Similarly, fast-growing, shade-intolerant trees usually dominate

stands regenerated in full light (as is the case in clearcutting and shelterwood systems). Finally, the use of genetically improved planting stock may require planting and tending in even-aged stands if their full growth potential is to be realized.

The size, age and vigour of the trees in the existing stand pose an additional constraint on the choice of a silvicultural system. A forest composed wholly of trees of advanced age and declining vigour ordinarily requires a heavy harvest cut, such as a clearcutting, seed tree, or shelterwood for safety and post-harvest site preparation reasons. Attempts to use the selection system in over-mature even-aged stands have consistently resulted in high mortality among remaining trees. The selection system is better suited to stands composed of trees that vary considerably in age, size and vigour.

Climate may also influence the choice of a silvicultural system. On some sites, a new seedling crop must be planted under a partial canopy of trees that protects the seedlings from frost or heat. Mountain and coastal sites that are subject to high velocity winds should not be partially cut. Clearcutting is usually required on windy sites and in shallow-rooted forests on wet soils to avoid the risk of windthrow to the residual trees. Snow depth and movement on slopes is also a consideration when selecting a silvicultural system for mountainous areas.

Favouring or discouraging particular wildlife species also affects the choice of silvicultural system. Silvicultural systems that provide clearings of appropriate size, shape, and dispersal for the production of low-browse vegetation favour browsing animals. Systems or rotation lengths that result in abundant seed production and mature trees for nest sites favour squirrels and cavity-nesting birds. In some timber types, the consumption of seed by birds and animals is serious enough to influence the choice of silvicultural systems and subsequent stand treatments.

Pest prevention and control measures are also factors. When stands are heavily attacked by disease or insect pests, it may be necessary to remove the infected trees or the entire stand. In some situations, such as infestations of dwarf mistletoe, the removal of the whole stand must be followed by burning to kill the parasitic plant. Depending on the site and the propensity for specific pests, the maintenance of an uneven-aged structure can be either a preventive management strategy or a welcome mat for infestation. For instance, maintaining a canopy over the regeneration, as in the shelterwood system, protects against infestation by pine shoot weevils, while maintaining it is deleterious to protecting a stand from spruce budworm defoliation.

The retention of a residual crop requires careful planning and handling. Residual stems are subject to damage during harvesting and injured trees can become pathways for disease and pests to enter stands.

Debris from harvesting may necessitate a silvicultural system that allows fire. In some forest types, the periodic use of prescribed fire reduces hazardous accumulations of flammable debris and undesirable undergrowth. Prescribed burning is applied chiefly to even-aged stands, because the young regeneration present in uneven-aged stands is easily killed by fire. However, uneven-aged management produces less debris, and hence the disposal of debris is less problematic.

OPERATIONAL CONSIDERATIONS

Operational and technical limitations, including the need to work in safety, will influence the choice of the silvicultural system. Timber type, size, density, soundness, understory density, and snag size and density all influence the system choice. The range of options is greatest for stands of uniform structure and few snags.

The slope and roughness of the terrain strongly influences both logging and silvicultural practices. Slopes greater than 30% restrict the available harvest options and subsequent silvicultural activities, such as slash burning and mechanical site preparation. A wider range of options is available for flatter and more uniform terrain. Table 5 presents the impacts on harvesting operations of seed tree, shelterwood and selection systems as compared to clearcutting. Though there are clearly cost implications associated with the increased difficulty in operations, comparative cost information is not readily available.

TABLE 5. The relative impact on harvesting operations of non-clearcutting silvicultural systems compared to clearcutting.

	EVEN-AGED		UNEVEN-AGED (SELECTION)	
	SEED TREE	SHELTERWOOD	SINGLE TREE	GROUP
Logging planning	-1	-2	-3	-2
Volume movement	-1	-2	-3	-2
Consolidation of operations	0	-1	-2	-1
Falling / Snag removal and skidding hazards	-1	-2	-3	-2
Influence of slope	-1	-2	-3	-2
Protection of advanced regeneration	0	+1	+2	+1
Road density	0	-1	-3	-2
Cost	-1	-2	-3	-2

-1 is more difficult than clearcutting; -2 is more difficult than -1; 0 is equivalent to clearcutting; +1 is less difficult than clearcutting; +2 is less difficult than +1.

The availability of resources, such as equipment and trained manpower, will affect the implementation of the silvicultural system as will the existing infrastructure, particularly the presence or absence of roads. Since roads can be costly in both economic and environmental terms, the advantages of the silvicultural system against the environmental and capital costs of the required road network must be weighed.

SOCIOECONOMIC CONSIDERATIONS

Socioeconomic considerations, the net monetary, social and environmental benefits of a silvicultural system to society, must be examined. In selecting a silvicultural system, the associated benefits and costs must be identified, the net benefits calculated, and the most desirable system chosen. While accomplishing these tasks in a satisfactory manner is far from simple, the process of assessment can be helpful nonetheless.

Economic Benefits of Timber Production

The economic benefits of timber harvesting to the people of British Columbia are enormous; if adopting a range of silvicultural systems results in increased harvesting costs, then these benefits may be reduced markedly. As a general statement, harvesting costs increase with the complexity of the silvicultural system; the simplest and least expensive system is progressive clearcutting, next is the seed tree approach, then shelterwood. The most complicated and expensive is the single tree selection system.

The forest industry is the largest single contributor to British Columbia's economy, producing almost 50% (by value) of our manufacturing output, employing 85,000 workers directly, and indirectly creating another 170,000 jobs through economic linkages. In total, the industry creates employment for about 20% of the B.C. labour force. In 1989, the contribution by the forest industry to federal, provincial and municipal governments totalled nearly three billion dollars.

These economic benefits derived annually from the forest industry are directly related to the rate of timber harvest, so that any reduction in harvesting will result in a reduction in the industry's economic benefits. Harvests are already scheduled to decline in British Columbia over the next few decades, as the industry makes the transition from logging old-growth to younger and smaller second-growth stands of timber. Higher harvesting costs could

further reduce harvest levels by reducing the area of land and volume of timber that can be harvested profitably. The operable area and volume of timber are extremely sensitive to changes in operating costs; a small increase in harvesting costs can result in a substantial reduction in operable timber land, with subsequent reductions in harvest levels, employment and government revenues.

The industry also loses revenue. One result of shrinking profit margins is that the industry will be less able to invest in measures that might enhance the future stock of timber, such as programs of genetic improvement and the incremental management of juvenile stands.

Other Resource Benefits

Timber is but one of the many benefits obtained from our forests. An economic evaluation of silvicultural systems must consider the benefits and costs in terms of all forest values. For example, while the economic losses from a reduction in timber harvesting due to higher cost silvicultural systems may be substantial, there may be compensating economic benefits to the province through tourism: replacing clearcuts with selection harvesting protects views and enhances recreational opportunities. However, the economic linkages of silvicultural systems to levels of tourism are less well understood than the linkages to timber harvesting. Consequently, the question of whether tourism benefits can offset the loss of timber benefits cannot be easily answered.

Environmental benefits associated with alternative silvicultural systems contribute to the sustainability of the forestry industry and return economic benefits in the long term. Unfortunately, these benefits are often difficult to quantify and impossible to value in monetary terms. Most of the non-timber benefits obtained from the forest are not traded in a market and so are not "priced". Nonetheless, these potential benefits may be the critical determinants and should be considered in the selection of silvicultural systems. The ease of quantifying timber benefits in monetary terms should not bias the economic analysis of alternative systems.

Short-Term and Long-Term Considerations

The timing of management actions and their effects will influence the valuation of costs and benefits. Economists typically assume that any costs incurred in the establishment, management and eventual harvesting of a forest stand must be deducted from the benefits produced by the stand. However, it is the nature of timber production that the majority of costs are incurred early in the life of the stand and the financial returns occur at harvest. The unpriced non-timber benefits flow throughout the life of the stand. Since society prefers to consume goods and services now rather than at some future date, future costs and benefits must be adjusted with a discount rate to account for this time preference. This discounting of future benefits emphasizes current costs over future benefits and favours the implementation of low-cost silvicultural systems unless all the future benefits can be correctly identified and quantified.

But what values can be assigned to future benefits from the forest? Predicting the price of timber products 70 or 80 years in the future is difficult enough; predicting how society will value ecological integrity, recreational opportunities and other non-timber values is impossible. These difficulties in quantifying future values should not preclude their consideration in the analysis of management scenarios.

Levels of Consideration

To complicate matters further, the socioeconomic implications of adopting alternative silvicultural systems must be considered at four levels of administration and planning: the stand, the forest, the region and the province. A desirable course of action at one level may not be favoured at another.

At the stand or cutblock level of planning, the efficiency of the silvicultural system is evaluated for a forest site or class of sites. Many methods of analysis determine the economic desirability of individual stand management regimes. At this level of planning, non-timber benefits and costs must be identified. Also, indirect costs and benefits must be identified and quantified if possible.

Forest level planning requires the simultaneous consideration of all the stands scheduled for harvesting for some long-term planning period. The goal of analysis at the forest level is to understand the impact of alternative silvicultural systems on current and projected levels of harvesting. At this level of planning, integrated resource management objectives may influence the implementation of silvicultural systems by specifying the spatial location and geometry of harvesting sites.

At the regional level, the direct effects of harvesting levels and forest industry employment associated with alternative silvicultural systems are evaluated. Indirect economic effects that occur through linkages to other sectors of the economy must also be considered.

At the provincial level, the main economic consideration is the different levels of provincial revenue associated with each silvicultural system.

Who Benefits? Who Pays?

The distribution of the benefits and costs — who receives the benefits and who pays the costs — may have serious political implications and is often more important than net benefits in selecting a course of action. The costs of adopting a silvicultural system which results in a reduced harvest level will be borne directly by forest workers through loss of employment, the forest industry through loss of production, the government through loss of revenue, and society through the loss of government services which were supported by revenue derived from the forest industry. The personal cost to the forestry worker is catastrophic, while the cost on a per capita basis to society may be minimal. On the other hand, the benefits, such as retention of biodiversity and ecological integrity, may accrue to society at large, perhaps even on a global scale.

The distribution of these costs and benefits is unlikely to be equitable and may run counter to other programmes to improve and stabilize social welfare in rural communities.

A COMPARISON OF RELATIVE IMPACTS OF SILVICULTURAL SYSTEMS

The impact of a specific silvicultural system on a forest site is a complex interaction of many factors, including all of those described above. Table 6 summarizes the relative impacts of clearcutting, shelterwood and selection systems on a B.C. coastal watershed.[3]

[3] Source: "The Clear-Cutting Issue". *Forest Perspectives*, April 1990. Produced by MacMillan Bloedel Limited.

A COMPARISON OF RELATIVE IMPACTS OF CLEAR-CUT, SHELTERWOOD AND SELECTION SYSTEMS APPLIED ON A COASTAL B.C. WATERSHED (>1,000 HECTARES, 100 YEAR CYCLE)

This table offers a simple comparison of the highly complex ecological and economic effects of applying these three regeneration systems in a watershed. A "watershed" basis is used rather than a "one opening" basis, to recognize that impacts must be seen in the context of a complete management cycle over 80 to 100 years.

Under Clear-cut and Shelterwood Systems, each forest area or stand is cut only once in a century. Under the Selection System, harvesting takes place throughout the entire watershed at five to 10-year intervals.

Once fully applied, the Clear-cut and Shelterwood Systems result in a mix of even-aged forest areas spread throughout this hypothetical watershed. The Selection System results in a single, uneven-aged forest over the entire watershed.

In each consideration below, the system with the least impact has been given a value of 0. Other systems are then rated against that. In other words, 0 represents the lowest impact, and higher numbers represent increasing impact.

IMPACT ON:	CLEAR-CUT	SHELTERWOOD	SELECTION	COMMENT
Flood peak	1	1	0	assume <40% clear-cut in 10 years
Landslide	4 (potential worst case)	2	0	differences will decrease with ability to set aside sensitive sites
Surface soil erosion	2 - 0	2 - 0	0	little difference with good practices
Road/trail density	0	1	2	based on European experiences
Soil nutrient loss	2	1	0	little difference with good practices
Ease of management	0 (also lowest cost)	1 (intermediate costs)	3 (also most costly)	selection system requires high skills
Water yield/quality	0 -1 (possible sediment)	0 - 1	0	no basis to assess sediment from selection system
Worker safety	0	2	4 - 2	hazard in selection system less as old growth cut
Timber quality	0 (could be coarse, branchy)	0 (could be coarse, branchy)	0 (could be diseased)	different factors will affect quality
Yield sustainability/volume yield	0 / 0	0 / 0	0 / 2	expect lower wood yield under selection
Aesthetics	4 - 2	2	0	lower on clear-cut if landscaped
Disease/insect risk	0 / 2	0 / 2	2 / 0	mistletoe and logging damage in selection system
Greenhouse effect	1 declining to 0	1 declining to 0	0	expect to be the same in 50 - 80 years
Deer, elk, cougar, wolf etc.	0 (high numbers)	0 (high numbers)	0 (lower numbers)	critical winter ranges must be protected; clear-cut's summer forage sustains high numbers
Squirrels, mice, voles, etc.	wide range of habitats	wide range of habitats	narrow range of habitats	
Soil fauna	wide range of habitats	wide range of habitats	narrow range of habitats	may not migrate well as clear-cut habitats change
Tree species diversity/gene pool	—	—	—	differences not measurable
Non-tree diversity/gene pool	open and closed habitats	open and closed habitats	closed habitats only	selection system poor for seral species
Birds - forest edge/open species	0	0	3	
- deep forest species	1	1	0	
- dead wood cavity nesters	0	0	0	no difference if snag treatment same
Fish/fish habitat	2 - 1	2 - 1	0	impact minimal with excellent management
Soil degradation	0 - 2	0 - 2	1 - 2	function of tree size and logging equipment

TABLE 6. A comparison of relative impacts of clearcut, shelterwood and selection systems applied on a coastal B.C. watershed (>1,000 hectares, 100-year cycle).

NEW FORESTRY[4]

New Forestry is not a silvicultural system *per se*; rather, it is a philosophy or approach to forest management that has as its basic premise the protection and maintenance of ecological systems. In New Forestry the ecological processes of the natural old-growth forest are models for designing the managed forest.

In general terms, New Forestry seeks to conserve more of the ecological values of the present forest, while maintaining timber production, than does conventional forestry. In this context it attempts to provide a means of accommodating society's desire for environmental health and stability while supplying its desire for wood products.

Despite its name, New Forestry is not altogether "new" forestry. Forest management in British Columbia, as in the Pacific Northwest U.S. where New Forestry has emerged, and elsewhere, has followed an ecological decision-making framework for many years.[5] What is new about New Forestry is its management focus on the perpetuation of some old-growth characteristics. This focus has resulted from recent research findings that have revealed more complex and important linkages between old trees, wildlife and fish, and ecosystem productivity, resilience and recovery than were previously understood. New Forestry advocates the protection of old-growth ecosystems for future study and the management of second-growth forests to achieve mature forests characteristics.

New Forestry seeks to preserve options. By combining the maintenance of ecological systems with the extraction of timber, it presents an alternative to the preservation versus timber production stalemate that dominates some forest landscapes. However, this alternative will likely result in reductions to allowable cuts and increases in logging and forest management costs.

New Forestry distinguishes management activities at the stand level and in the larger landscape. Among its objectives are: to maintain a structurally complex stand at the forest level; at the landscape level, to integrate forest activities to achieve biological diversity; to manage fish and wildlife populations of economic value; and to control cumulative watershed effects on stream temperature, sediment loads, erosion and flooding.

Figures 7 and 8 compare the succession of a conventional clearcutting system to the succession under New Forestry management. The forest managed with conventional clearcuts (Figure 7) would have snags and down logs and would be considered old-growth in its last stage. However, after the first harvest, this old-growth stage of succession will never be reached in future rotations which are often on 90-100 years. New Forestry management (Figure 8) maintains some of the desired old-growth characteristics (green trees, snags, and fallen dead trees) throughout the successive harvest cycles. Retained green trees may become "veterans," or trees which are much larger and older than the harvested crop. These old trees may be left to die naturally or be intentionally killed to become snags and, eventually, coarse woody debris.[6]

[4] This chapter is based largely upon "New Forestry Practices. A Report for the Management Practices Team of the Old Growth Strategy Working Group", Douglas Hopwood, 1990.

[5] Pojar, J., Klinka, K. and D.V. Meidinger. 1987. Biogeoclimatic ecosystem classification in B.C.

[6] Coarse woody debris (CWD) comprises large diameter (30 - 60 cm) logs or broken pieces of logs. CWD left on-site for ecological reasons may be indistinguishable from conventional logging slash.

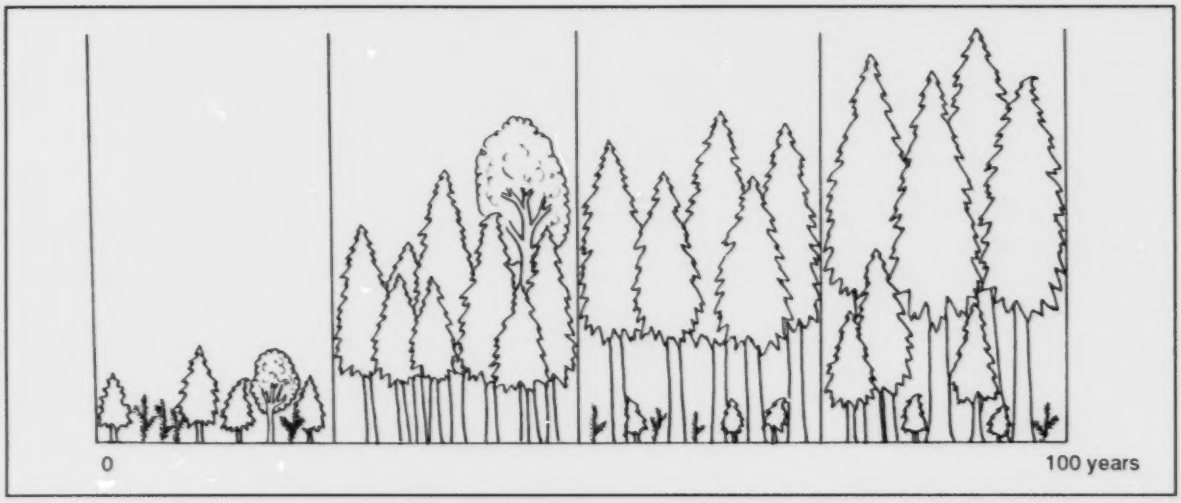

Figure 7. **Succession of Clearcutting Stand Structure**

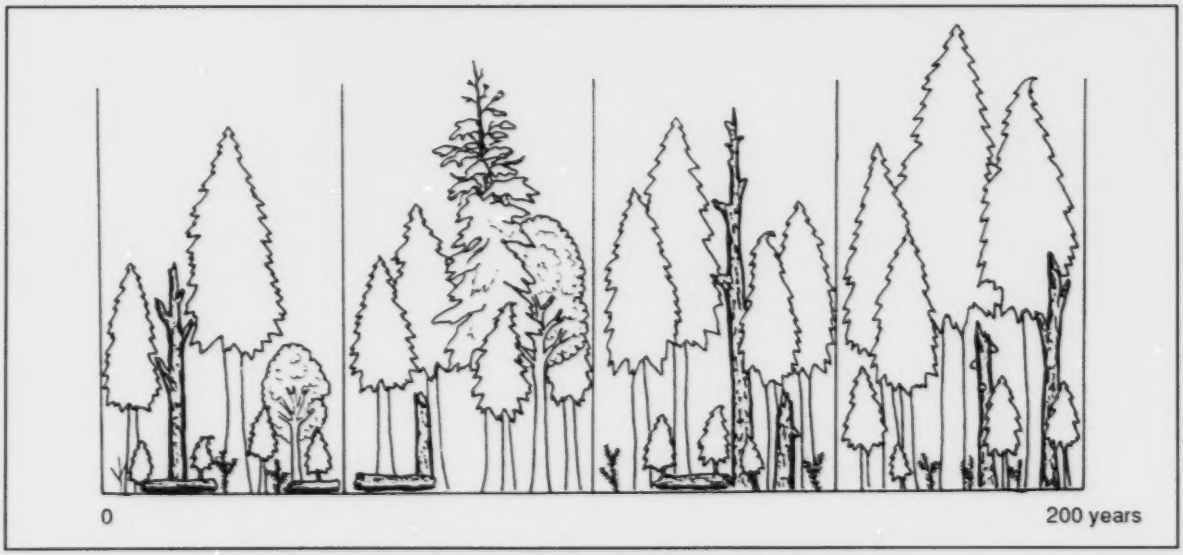

Figure 8. **Succession of New Forestry Stand Structure**

NEW FORESTRY SEEKS TO:	NEW FORESTRY IS NOT INTENDED TO:
• maintain complex and diverse ecosystems • integrate the protection of ecological values with the production of timber and other commodities • provide a realistic and ecologically sound alternative between intensive timber production "working" forests and large preserved forests	• preclude the use of clearcutting, but to use the system best-suited ecologically to the site • exclude the use of incremental silvicultural techniques to enhance tree growth, providing that ecosystem integrity is maintained

APPLICABILITY OF NEW FORESTRY PRACTICES TO B.C.

The philosophy and practice of New Forestry has developed in the Pacific Northwest United States to meet specific forest management goals on specific sites. The first question to be asked regarding the applicability of New Forestry in British Columbia must concern the similarity of forest ecotypes and forest management goals in the two regions and present differences in forest management practices.

Most New Forestry research has occurred in the Western Hemlock zone of the U.S. Pacific Northwest. This zone is quite similar to British Columbia's Coastal Western Hemlock zone, especially in the old-growth Douglas-fir forests of the drier CWH subzones. Much general information and experience from the U.S. studies can be related to comparable forests in B.C.[7] The major ecological difference between the U.S. and B.C. sites lies in the soil parent material and soil depth; much of B.C.'s coastal forest lands were glaciated, resulting in shallower soils than those of the Pacific Northwest. The extent to which this may affect the implementation of New Forestry practices in B.C. is not known at this time. Wildlife species are similar between the two regions, though B.C. has additional species to those of the Pacific Northwest.

The two regions have somewhat similar management plans. Strong public advocacy groups for ecological and environmental values (e.g. wilderness and wildlife preservation) as well as for the economic values of the timber industry exist in each region. Both regions subscribe to the multiple use of forests and both are concerned with management for biological diversity. In the U.S. the latter is a legislated requirement through the *National Forest Management Act*, while in B.C., it is a recent policy statement of both the Wildlife Program of the Ministry of Environment and the Ministry of Forests.

A significant difference between the U.S. Pacific Northwest and British Columbia lies in the relative importance of timber production on U.S. National Forests and on B.C. provincial Crown land. Almost 90% of the timber in B.C. is produced on provincial Crown land, while most of the timber produced in the U.S. Pacific Northwest comes from private lands. As a result, timber production on National Forests, where New Forestry is practiced, is a much lower priority than on British Columbia's Crown land.

In both regions a significant portion of the forest land base has been harvested and regenerated as plantations; both areas are experiencing growing public pressure to preserve the remaining old-growth. The regions share a similar age-class gap in timber supply, hence the forest industries of both regions will depend on old-growth for the next few decades. As a result, this period is critical in determining the long-term mix of plantations and reserved old-growth in the regions. However, the difference in logging history between the U.S. Pacific Northwest (primarily patch clearcutting resulting in a fragmented patchwork landscape of old-growth) and British Columbia (larger clearcuts, frequently progressing up a drainage) may mean that the landscape-level practices from the U.S. Pacific Northwest will not apply to B.C.

While the ecological and social similarities between the regions do not justify wholesale adoption of New Forestry in B.C., they indicate an opportunity for monitoring the experience of forest managers in the Pacific Northwest as they apply New Forestry methods.

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[7] In applying New Forestry concepts to British Columbia, the emphasis on 'comparable forests' must be stressed. Most of B.C.'s coastal forests are not comparable to the forests in which New Forestry has developed in the Pacific Northwest.

HOW NEW FORESTRY DIFFERS FROM CURRENT B.C. FOREST MANAGEMENT PRACTICES	HOW NEW FORESTRY IS SIMILAR TO CURRENT B.C. FOREST MANAGEMENT PRACTICES
• focuses on old-growth retention through minimum forest fragmentation • manages second-growth stands to provide old-growth habitat characteristics • encourages diverse stand structure (age class, composition, size) vs. even-aged management • advocates longer rotations • emphasizes non-timber values and ecosystem management	• supports sustained yield timber production, but at a lower AAC • advocates multiple use • includes components such as snags, green tree retention, streamside buffer strips, wildlife habitat • favours clearcutting and shelterwood over selection • encourages both natural and artificial regeneration

IMPLEMENTATION ISSUES

Several major issues must be addressed in the application of New Forestry methods in British Columbia.

Safety

Worker safety is a major issue with respect to the implementation of New Forestry. In British Columbia, 55% of the 87 logging fatalities reported in 1987 involved practices such as felling into standing timber and leaving snags, standing green trees and more coarse woody debris on cutblocks. The B.C. Workers' Compensation Board views the leaving of snags as a hazard to workers, both in harvesting and subsequent silviculture operations, such as planting, brushing, surveying and spacing. These concerns also extend to the leaving of standing green trees and the creation of snags on logged blocks.

The U.S. Forest Service has developed guidelines for the selection and treatment of live or dead standing trees for wildlife habitat. Similar guidelines for British Columbia are being developed by the Wildlife Tree Committee.

Logging Systems

Timber extraction under New Forestry will require new logging technology and techniques to maintain ecological diversity, ensure worker safety and minimize site disturbance and damage to standing trees. It is anticipated that there will be greater use of skyline systems, hoe-chucking and helicopter logging of steep and sensitive slopes. High lead and grapple yarding systems may remain viable in areas with well-developed access. Where ground skidding equipment is to be used, falling and skidding patterns may require alterations.

Costs

The costs of timber extraction and subsequent silvicultural treatments can be expected to be significantly higher than those currently associated with clearcutting in B.C. Skyline logging is more expensive than high lead, which is more expensive than grapple yarding. The degree to which these costs are offset by savings in decreased road construction associated with skylines is unclear. Logging planning costs can also be expected to increase under New Forestry.

Aesthetics

New Forestry will not solve the aesthetic concerns currently associated with clearcutting systems in the province. The encouragement of a heterogeneous stand structure and the practice of leaving down logs, standing snags and green trees has led to applications of New Forestry being described as 'sloppy clearcuts'. The need to landscape cutblocks will remain, and selection systems may also be required in areas of high visual significance.

Forest Protection

The retention of snags and the reduction or elimination of slashburning may create fire and pest protection problems in some stands. The possible effects of a diverse stand structure on the incidence and level of infestation of insect pests, such as bark beetle, or diseases, such as root rot, are not known. Similarly, the potential benefits associated with maintaining a more complete bird, animal and insect predator-prey relationship is unknown. It is expected that pest control will be more difficult in the absence of slashburning; careful selection of green leave trees and snags will be required, especially with diseases such as mistletoe. Snags create serious fire protection concerns in areas prone to lightning. In areas of high lightning risk, it may be advisable to remove snags or not to log.

Non-Recoverable Losses

In British Columbia, the value of green trees to be left on the site under New Forestry management is projected to be between 10% and 20% of the total value of the standing timber. These trees may be harvested during a second pass; however, heavy windthrow or other risks may preclude the retention of green trees on some sites.

Site Preparation and Reforestation

The costs of reforestation will likely increase due to obstacles created by the retention of snags, green standing timber, and coarse woody debris.

Broadcast burning presents an obvious operational problem for the retention of snags and standing green material. New broadcast burning techniques must be developed for the New Forestry system and increases in site preparation costs should be expected.

In many ecosystems, current practices call for site preparation to control undesirable vegetation to ensure good crop tree survival and adequate growth rates. Vegetation management becomes problematic under New Forestry due to constraints on site preparation methods. However, the desire for a diverse stand structure under New Forestry may reduce the importance of vegetation management.

NEW FORESTRY OPTIONS AND OPPORTUNITIES

New Forestry stresses the management of forests to maintain elements of natural ecosystems. Among the possible benefits from this new management perspective may be a potential middle ground for timber and preservationist interests that permits some timber harvesting in old-growth stands while allowing the preservation of others. As stated earlier, New Forestry may preserve options by slowing the liquidation of old-growth stands until second-growth stands can assume some of the harvesting pressure and/or until forest managers have developed systems of incorporating elements of old-growth ecosystems into the management of second-growth stands.

New Forestry does not address the current clearcutting versus selection system controversy. Nor can it please everyone. There are serious criticisms concerning its efficacy as a safe and profitable means of timber production, a healthy system for stand renewal, and its applicability to a range of biogeoclimatic zones in the province. Among the litany of concerns are the propensity for windfall, the likelihood of decreased timber yields, the hazard relating

to slash accumulation, the potential for damage to the understory, and the visual effects. From the non-timber production side there are concerns that it is a less effective means of preserving old-growth than locking it up in reserves.

Some feeling exists that New Forestry is out-of-date in attempting to address timber production in co-existence with non-timber values.[8] Increasingly, multiple use management is practiced as single dominant uses which are separated spatially (e.g. riparian buffers, timber plantations, wildlife corridors) in a landscape. There is also concern that New Forestry will preclude incremental management of plantation forests, thereby reducing timber production on those lands available for harvesting. Another concern relates to the technical basis of New Forestry and the lack of operational field testing of some of its concepts. Atkinson (1990) argues that the preferred alternative to the application of New Forestry is the modification of plantation forestry to address other forest values. This would include mixing species, minimizing the impacts of road building, harvesting and site preparation, and maintaining stocking levels and biological diversity through thinning.

At this time, the extent to which New Forestry can be successfully applied in British Columbia is not clear. If it can do no more than provide a common focus for investigation of forest management by different forest resource interests, it will be a worthwhile approach. Properly applied, it can, in theory, maintain biodiversity, long-term productivity and ecological resilience of forests managed for timber production.

The first steps towards clarifying what New Forestry can and cannot do for B.C. are to monitor New Forestry's effectiveness as a management strategy in the Pacific Northwest and later, if warranted, initiate limited field testing of practices not already in use in British Columbia.

[8] In a paper presented to the Annual Meeting of the Oregon Society of American Foresters in May 1990, William Atkinson presents a number of arguments against New Forestry. This paper is generally felt to represent the major criticisms of New Forestry held by professional foresters.

SILVICULTURAL ISSUES

To this point, this report has presented the concepts and implementation of various silvicultural systems and New Forestry. In addition, the various biological, management, ecological and economic factors which provide the framework for selection have been described. This section will outline the public attitudes and some of the issues of concern that have been raised about the application of particular silvicultural systems in British Columbia.

PUBLIC ATTITUDES

Clearcutting grew as a contentious issue between the public and the forest industry during the mid-1980s. A 1989 national survey of Canadian public opinion on forestry issues commissioned by Forestry Canada[9] revealed that the Canadian public is very concerned about the environment. In British Columbia, 57% of respondents viewed environmental impact as the most important consideration in forest land use decisions, followed by economic value (17%), job creation (9%) and aesthetic impact (3%). For British Columbians, overcutting and replanting were the major issues of concern.

A few questions from this survey sought to specifically identify public perceptions and opinions regarding clearcutting. Nationally, 81% of respondents strongly or somewhat agreed with the statement "I get personally upset when I see a large area of clearcut forest", and 57% disagreed with the statement "Environmentalists go too far in trying to restrict logging".

Sixty-seven percent of the B.C. respondents disapproved somewhat or strongly of clearcutting as a primary logging method in Canada. Nationally, the reasons given for opposing clearcutting included:

- ruins forests 37%
- wasteful of wood 27%
- interferes with nature 20%
- bad for erosion 16%
- bad for wildlife 15%
- looks bad 12%
- areas cut too large 10%
- indiscriminate cutting 6%
- other reasons 8%

Selection cutting was favoured by the public. In Canada, 53% of respondents said it was very important and 32% said it was somewhat important that selection cutting be used as an alternative to clearcutting, despite its greater cost. In selecting a silvicultural system, respondents indicated the most important consideration was how fast/ successfully the forest grows back, followed by the effect on wildlife and how the land looked after logging. The cost of logging method was rated as the least important of these considerations.

Underlying the issue of the selection of a silvicultural system is the broader issue of public trust. The public has lost confidence in the ability of government and the forest companies to effectively manage their forests and believes that harvesting regulations are either insufficient or are not uniformly enforced. Other users of the forests, including trappers, guides, ranchers and resorts owners are concerned about the sustainability of their livelihoods.

The public links many of the current environmental issues to clearcutting. Clearcutting is blamed for destroying the world's forests and contributing to the deterioration of the world environment through global warming — as a result of the release of carbon dioxide through slashburning and the subsequent loss of the carbon dioxide absorption capacity of the forest. The public feels that clearcuts are too big, are "unnatural" and increase losses to biological diversity, wilderness, fish and wildlife habitat, recreation opportunities and aesthetic values.

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[9] Environics Research Group Limited, 1989.

Special Interest Groups

To communicate their desires to the government and industry, British Columbians have formed numerous special interest and advocacy groups. These include the Western Canada Wilderness Committee, the Sierra Club of Western Canada, the Canadian Parks and Wilderness Society, the Heritage Forests Society, Friends of Clayoquot Sound, Share the Stein, Women in Timber, and the Federation of B.C. Woodlot Owner Associations. The forest industry, professional foresters, forest technicians and union workers have similar organizations.

Special interest groups develop position statements which contribute to the debate on forest sector issues. For example, the Sierra Club of Western Canada has a vision of the "working forest" being managed not only for production of timber but also for the maintenance of biological diversity and long-term forest productivity. The Sierra Club rejects the notion that clearcutting mimics natural forest disturbances such as wildfire. It maintains that where timber extraction occurs it must be conducted in a manner that simulates the natural process of forest disturbance and succession to protect and enhance the non-timber values and minimize long-term ecological disruption. For these reasons, the Sierra Club supports the New Forestry approach to forest management.

From a forest worker's perspective, the International Woodworkers of America (Canada) (IWA) supports the use of silvicultural systems other than clearcutting if they are ecologically warranted, but is particularly concerned about worker safety. The IWA advocates the review of silvicultural systems by all parties concerned (including itself and the Workers' Compensation Board), and analysing the effects of different systems on local allowable cuts and economies.

ISSUES OF CONCERN

The issues raised with respect to forest management and the choice of silvicultural systems in British Columbia include: aesthetics, biological diversity, economic efficiency of timber production, maintenance of environmental and ecological integrity, worker safety, and the preservation of old-growth ecosystems and non-timber values in forest management planning.

Aesthetics

The public finds clearcuts ugly, but the forest sector argues that they are silviculturally appropriate, economically efficient and safe for woods workers. Social, environmental, and economic circumstances under which alternatives to clearcutting are feasible must be determined. Also, modifications of current clearcutting practices to meet public and forest sector needs (e.g. landscaping of clearcuts, reduction in size of opening, arrangement of clearcuts in a landscape and timing of green-up prior to new harvesting) must be pursued.

Biodiversity

Conventional timber production often includes managing forests for one seral stage, specified species of timber crops and relatively short rotations. These practices reduce the diversity in plant, animal and insect populations in the forest landscape. While the full benefits of maintaining biological diversity are not known, there is growing opinion that greater diversity in forest ecosystems is preferable to less. Biodiversity provides a protective buffer against pests and fire and contributes to the stability of the ecosystem. It also maintains options, both for future study and future management objectives.

Environmental Health

Both conventional forest management and New Forestry have positive and negative effects on the environment. The major safeguards to environmental health include: preventing erosion and slumping due to increased water flows; minimizing soil compaction and loss of site productivity due to the use of heavy equipment; and coordinating harvesting activities with forest protection goals. Conventional forestry practices seek to minimize impacts on

individual sites, through sensitive road building, yarding and site preparation techniques. New Forestry seeks to maintain environmental health by managing the integrity and stability of whole ecosystems.

Protection

Forest protection measures prevent the conditions that invite fire, insects and disease into forest stands. Specific fire protection strategies include minimizing the build-up of slash and breaking up the fuel complex on-site. Protection strategies against insects include: minimizing the creation of even-aged monocultures; maintaining stand vigour through tending activities; and, where harvesting is done in more than one pass, minimizing the damage to understory trees. Where specific pests are anticipated, silvicultural systems can create a stand structure that can discourage the pest.

Worker Safety

Worker safety is a critical issue in all forestry operations, from the woodlands to the mills. Harvesting, bucking, yarding and loading, perhaps the most dangerous activities, have operational procedures and guidelines provided by Workers' Compensation Board and forest companies. Worker safety often appears as a major issue with respect to the use of various silvicultural systems. Clearcutting is presented as the safest means of harvesting, especially in old-growth stands subject to decay; seed tree, shelterwood and selection systems represent increasingly risky circumstances for the faller. To ensure worker safety, guidelines have been developed for the retention of snags for wildlife purposes. Similar guidelines and worker training programs must be developed for the retention of green trees and the creation of old-growth characteristics.

Old-Growth Forests

Old-growth stands are subject to the greatest pressure in British Columbia since they are the stage at which many forest values culminate. They have the biggest trees, with the greatest timber and aesthetic values. Many wildlife species of high-viewing value, such as ungulates and cavity-nesting birds, depend on old-growth forests for seasonal habitats. Old-growth forests also contain cultural and spiritual values and provide unique recreational experiences.

Both the forest and tourism industries depend on old-growth forests; the former as a source of timber for the next twenty to thirty years until second-growth stands are available for harvesting, the latter for long-term habitats for wildlife and for people. And as much as they are valued for what is known about them, old-growth ecosystems are also valued for their richness and complexity and what has yet to be learned from them.

Because of the significance of old-growth stands, an Old Growth Strategy Task Force was established in 1989. Its mandate is to explore old-growth issues, definitions, objectives, research and inventory requirements with the ultimate goal of developing a strategy for old-growth management in British Columbia.

The silvicultural issue with respect to old-growth forests has two parts — should some forests be managed as old-growth ecosystems (i.e. New Forestry), and which silvicultural systems are best suited (with respect to all the above issues) to old-growth harvesting and renewal?

Economics

Two levels of costs must be considered in assessing the economics of different silvicultural systems in achieving timber production objectives: the costs of implementation and the costs of site productivity and timber yields. Due to the differences in sites and the influence of factors such as soil type and depth, terrain, and vegetation on the costs of implementation, this assessment must be made on a site-specific basis.

Non-Timber Resources/Values

In recent years, the public has increasingly valued its non-timber resources and forest experiences. As a result, these values are being integrated with timber production goals. Integrating uses (and values) in forest landscapes most commonly involves assigning a resource emphasis to an area and managing primarily for that use in consideration of other values on-site. As a result, multiple use objectives are most commonly achieved by undertaking primarily single use management on separate areas of the forest landscape — streamside buffers, visual and wildlife corridors, and plantation forests are some examples. In practice, some uses are more complementary than others.

From a silvicultural point of view, the task at hand requires adapting and developing systems to achieve specific non-timber management objectives. This is already being done in some cases, such as the use of selection and shelterwood systems to maintain a diverse age structure and create understory browse for wildlife.

RECOMMENDATIONS

Information is a limiting factor when developing management strategies. In British Columbia, this reality is exacerbated by the presence of many different forest ecosystems. For more informed decision-making the effects and implications of implementing a range of silvicultural systems must be evaluated. B.C. must therefore augment its current research program with studies of old-growth forest ecosystems and of the implications of different silvicultural systems in each of its biogeoclimatic subzones.

The major recommendations of this report are to develop an information base on silvicultural systems and New Forestry, and a system for the communication of these concepts to field personnel, decision-makers and the public. Recommendations pertaining to specific issues raised throughout the report are presented under each of these major report recommendations.

Establish a program of research into the application of alternative silvicultural systems in British Columbia.

Silvicultural Systems

The effects of a silvicultural system vary according to the ecosystem in which it is applied. More complete information is needed on the suitability of the various silvicultural systems to achieve specific timber and non-timber management goals in different forest ecosystems.

- Retrospective studies should be undertaken in regions where alternative silvicultural systems have been implemented. This will provide information on the effects of different systems in the different ecological subzones.
- Funding must be secured to support ongoing studies of the effects of various silvicultural systems in different ecosystems of the province.
- Testing should document the effects of each silvicultural system on biodiversity, regeneration success, the growth and yield of crop trees, and non-timber objectives.
- Ecosystems associations where silvicultural systems other than clearcutting could be an option should be identified throughout the province.
- A bibliography of research work applicable to silvicultural systems in British Columbia should be assembled.
- A task force should be established with representatives from all interested agencies to identify research needs and priority research projects (e.g. the FRDA Technical Advisory Committees).

Forest Protection

More information is needed regarding the implications of silvicultural systems for protection issues.

- A literature review should be prepared which discusses specific damaging agents, potential hazards and control measures in the context of the various silvicultural systems (e.g. damage from ungulates and small mammals, insects, disease and mechanical damage from forestry operations).
- Research should fill in existing information gaps (e.g. the potential for root rots and measures for their control in all silvicultural systems).
- The implications of various silvicultural systems for fuel management, soil and slope stability, windthrow and snow damage should be documented.

Non-Timber Values

Information is needed on the effectiveness of various silvicultural systems in achieving non-timber management goals including water quality and supply, riparian management, maintenance or enhancement of wildlife habitat,

aesthetic and recreation values. Information currently available is limited to specific watersheds, corridors or wildlife species and should be expanded to other environments and species.

Landscape-Level Planning

Total chance planning must be encouraged and implemented. Forest planning and management must begin to concern itself with the large picture of activities at the district, regional and provincial levels. To maintain future options, development must minimize landscape fragmentation by various development activities carried out without knowledge or consideration of one another.

Operational Costs

Information on operational costs for silvicultural systems other than clearcutting is limited. The cost of implementing each combination of silvicultural system, ecosystem and terrain type should be obtained. This will allow the valuation system to correctly account for silvicultural systems.

Administration

The provincial ministries of Forests, Environment, Parks, Tourism, and Crown Lands, and the federal Department of Fisheries and Oceans and Forestry Canada all deal with forest land use. Their collective administrative effects on the objectives and implementation of silvicultural systems should be reviewed.

The Ministry of Forests' stumpage rate calculations assume that timber will be harvested to meet all requirements imposed by the Ministry. This current policy may discourage voluntary adoption of those silvicultural systems which may cost more to implement and are not required by the Ministry, but may better serve non-timber management objectives. The timber pricing system should be reviewed and amended to recognize costs associated with these objectives.

Establish an extension and demonstration program to transfer research findings on the application and implementation of silvicultural systems and New Forestry in B.C. to professional, technical and forest worker audiences.

- Regional guidelines on the application of various silvicultural systems should be developed to support both planning and field operations.
- Guidelines and training programs must be established to ensure: site-specific selection of a silvicultural system; achievement of designated management objectives; implementation of the selected system; and maintenance of safe working conditions.
- Demonstration areas should be developed in all forest ecosystems to illustrate the application and effects of various silvicultural systems.

Establish a communications program to provide the public with information on forest management practices and to clarify the concepts, application and implications of alternative silvicultural systems.

- Ongoing monitoring of public concerns is required to ensure that silvicultural systems address public interests and to maintain informed public involvement in the planning processes.
- Public involvement in planning the use and management of forest resources should be encouraged.
- A variety of communication formats should be developed to provide information to technical and public audiences including local field trips, open house information sessions, public forums and school programs.

REFERENCES

Amman, G.D., Lessard, G.C., Rasmussen, L.A. and C.G. O'Neil. 1989. Lodgepole pine vigour, regeneration and infestation by mountain pine beetle following partial cutting on the Shoshone National Forest, Wyoming. Res. Note Int. Ogden, UT. U.S. Dep. Agric. For. Serv. Intermountain Research Station. 7pp.

Atkinson, William. 1990. Another View of New Forestry. Paper presented to the Annual Meeting of the Oregon Society of American Foresters, Eugene, Oregon.

B.C. Ministry of Forests. 1990. Annual Report 1988/1989. Victoria, B.C. 91pp.

Brown, J. K. 1979. Influence of harvesting and residues on fuel and fire management. *In* Environmental consequences of timber harvesting in Rocky Mountain coniferous forests. Symposium Proceedings, Missoula, MT. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. INT-90: 417-432.

Camenzind, W.D. 1989. The review of silvicultural systems and their applicability to the Prince Rupert Forest Region interior subzones. B.C. Ministry of Forests, Prince Rupert Region, Smithers, B.C.

Carlson, C.E. and W.N. Wulf. 1989. Silvicultural strategies to reduce stand and forest susceptibility to the western spruce budworm. U. S. Dep. Agric. For. Serv. Handb. No. 767. 31pp.

Council of Forest Industries of B.C. 1990. British Columbia Forest Industry Fact Book 1990.

Environics Research Group Limited. 1989. National Survey of Canadian Public Opinion on Forestry Issues. Forestry Canada.

Farnden, C., Moss, I. and B. Hunter. 1988. The acceptability of western hemlock for regeneration in the ICHmcZ and ICHmc3 subzone variants. B.C. Ministry of Forests, Prince Rupert Forest Region, Smithers, B.C. Contract report.

Franklin, J.E., Emmingham, E. and R. Jaszkowski. 1983. True fir - hemlock. Silvicultural systems of the major forest types of the United States. U.S. Dep. Agric. For. Serv. Handb. No. 445.

Hopwood, Douglas. 1990. New Forestry Practices. A Report for the Management Practices Team of the Old Growth Strategy Working Group.

Knight, E. 1990. Reforestation in British Columbia: A Brief History. *In* Regenerating British Columbia's Forests, University of British Columbia Press, Vancouver.

Lotan,J.E. and R.R. Alexander. 1973. Lodgepole pine. *In* Silvicultural systems of the major forest types of the United States. U.S. Dep. Agric. For. Serv. Handb. No. 445. pp 42-43.

MacMillan Bloedel Limited. 1990. The Clear-Cutting Issue. *Forest Perspectives.* April.

Martin, C.W. and R.D. Harr. 1988. Logging of mature Douglas-fir in Western Oregon has little effect on nutrient output budget. Can J. For. Res. 19:35-43.

McGregor, M.D. and D.M. Cole. 1985. Integrating management strategies for the mountain pine beetle with multiple resource management of lodgepole pine forests. U.S. Dep. Agric. For. Serv. INT-174 Gen. Tech. Rep. 64pp.

Parmeter, J. R. Jr. 1978. Forest stand dynamics and ecological factors in relation to dwarf mistletoe spread, impact and control. *In* Proceedings of a symposium on dwarf mistletoe control through forest management. University of California, Berkeley, California.

Pojar, J., Klinka, K. and D.V. Meidinger. 1987. Biogeoclimatic ecosystem classification in British Columbia. For. Ecol. Manage. 22:119-154.

Ruth, R.H. and A.S. Harris. 1979. Management of western hemlock - Sitka spruce forests for timber production. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. PNW-88. 197pp.

Schmidt, W.C., Wellner, C.A. and R.R. Alexander. 1973. Engelmann spruce - subalpine fir. *In Silvicultural systems of the major forest types of the United States. U.S. Dep. Agric. For. Serv. Handb. No. 445. pp. 40-41.*

Schulting, J. 1988. Productivity of and heart rot incidence in western hemlock (*Tsuga heterophylla*, (R.A.F.) SARG.) in the interior cedar hemlock biogeoclimatic zones of B.C. Draft FRDA Report No. 3.28.

Seidel, K.W. 1983. Mixed pine - fir of eastern Oregon and Washington. *In Silvicultural systems of the major forest types of the United States. U.S. Dep. Agric. For. Serv. Handb. No. 445. pp. 15-17*

Seidel, K.W. and P.H. Cochran. 1981. Silviculture of mixed conifer forests in eastern Oregon and Washington. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. PNW-121. 70pp.

Williamson, R.L. 1973. Coastal Douglas-fir. *In Silvicultural systems of the major forest types of the United States. U.S. Dep. Agric. For. Serv. Handb. No. 445. pp. 8-10.*

Appendix 1
GLOSSARY

advance regeneration: young trees that have become established naturally before any cutting begins.

biological diversity (biodiversity): the diversity of living things. Three levels of biological diversity are genetic diversity, species diversity and ecosystem diversity.

clearcutting system: an even-aged silvicultural system that involves the harvesting of all trees from an area of forest land in a single cut.

coarse woody debris (CWD): large diameter (30-60 cm) logs or broken pieces of logs.

even-aged management: management practices that create or maintain a forest stand or forest type in which relatively small (10-20 year) age differences exist between individual trees.

extension services: assistance provided to woodland operators; may include help with the preparation of forest management plans, training in specific forestry practices, etc.

geographic information system: a computer system that maintains and manipulates the spatial aspects (e.g., boundaries of stands) of geographic data, in addition to providing standard database query functions.

green tree retention: maintaining live trees standing after harvesting for wildlife purposes and as future sources of coarse woody debris.

high grading: the removal of only the best trees from a stand, often resulting in a poor-quality residual stand.

high lead system: a logging system that uses cables rigged to a spar so that one end of the log can be lifted during yarding.

landing: the area where logs are collected for loading.

mean annual increment (m.a.i.): the average annual increase in volume of individual trees or stands up to the specified point in time. The m.a.i. changes with different growth phases in a tree's life, being highest in the middle years and then slowly decreasing with age. The point at which the m.a.i. peaks is commonly used to identify the biological maturity of the tree and its readiness for harvesting.

New Forestry: a philosophy or approach to forest management that has as its basic premise the protection and maintenance of ecological systems. In New Forestry, the ecological processes of the natural old-growth forest are being used as a model to guide the design of the managed forest.

partial cutting: a general term for tree removal other than clearcutting; only part of the stand is removed.

riparian zone: area that borders water bodies and contains a high water table and possibly plants requiring saturated soils.

rotation: the interval between cuts that remove the forest canopy.

seed tree system: an even-aged silvicultural system that leaves selected standing trees scattered throughout the cutblock to provide seed sources for natural regeneration. The number of seed trees to be left depends on the desired number of seedlings per hectare, the seed crop frequency, seed dissemination distance and the length of time that the seedbed remains receptive.

selection system:	an uneven-aged silvicultural system in which trees are harvested individually or in small groups continuously at relatively short intervals.
selective harvesting:	the removal of selected trees from a stand according to some set of guidelines or objectives; in the past, this has often been practiced as 'high grading'.
seral community:	a pioneer or any late ecological successional community before the development of a climax community.
shelterwood system:	an even-aged silvicultural system which involves the harvesting of a more or less regular and mature crop with the objective of establishing a new crop under the protection of the old.
silviculture:	the art and science of growing and tending a forest.
silvicultural system:	a system of forest treatments whereby forests are tended, harvested and regenerated.
skidding:	the process of sliding/dragging logs from the stump to a landing; the term usually refers to ground-based logging operations as opposed to high lead operations.
skyline:	a type of cable logging in which the mainline is stationary as a carriage moves along it carrying logs from the felling site to the landing.
spar:	a tree or pole in which rigging is hung for cable-yarding systems.
stand:	a community of trees sufficiently uniform in species, age, arrangement or condition to be distinguishable as a group from the forest or other growth on an area.
succession:	the replacement of one plant community by another in progressive development toward climax vegetation.
total chance planning:	early planning over an entire development area for the best overall realization of all objectives identified by broader planning.
utilization standards:	the utilization limits (stump height and top diameter inside bark) which define the trees considered to be commercially saleable by the Ministry of Forests and therefore, the dimensions of all trees that must be cut and removed from Crown land harvesting operations.
uneven-aged management:	management practices that create or maintain a forest stand or forest type with a wide range of ages and sizes of trees.
watershed:	an area that collects and discharges water into a single main stream through a series of smaller tributaries.
yarding:	moving trees or logs from felling site to roadside with cable, winch or helicopter.

Appendix 2
SILVICULTURAL SYSTEMS AND FOREST PROTECTION

As part of the planning effort used to formulate and implement a silvicultural system, the form of protection measures must be evaluated. Protection is intimately associated with risk management. All silvicultural systems have a capital investment which needs to be protected. In even-aged management the investment depends on the next crop (whether naturally or artificially regenerated), in uneven-aged management it depends on the residual growing stock.

FIRE

Fire has a major impact on the forest environment, regardless of the silvicultural system in place. In general, as slash buildup and its uniformity of dispersion increases on site, the fire hazard increases.

In a study comparing fuel and fire behaviour potential in lodgepole pine and Douglas-fir-western larch timber types, Brown (1979) investigated clearcutting, group selection and uniform shelterwood sites, logged to various utilization standards. They found that fuel and fire risk were unaffected by the silvicultural system used, and that fire risk relied more upon the utilization standard and the method of skidding.

While clearcutting creates the largest amount of fuel, it also provides the greatest flexibility in the choice of hazard abatement, including broadcast burning or mechanical treatment. In non-clearcut stands, the options for reducing fire hazard are more limited and the risk of loss is therefore higher.

Shelterwood systems, especially uniform shelterwood, have the fewest options due to the combination of significant slash loading and the limited slash abatement techniques. Broadcast burning is possible but has many inherent problems which may destroy the shelterwood trees. Mechanical options are also reduced, especially as the slope increases beyond 15%. While the risk of ignition within a shelterwood system is less than in a clearcut, the risk of fire loss is higher, due to the value of merchantable timber present.

Single tree selection produces the least amount of slash and the lowest risk of fire because of the shade and moisture retention within the stand and forest floor. However, once a fire occurs, suppression can be difficult due to the vertical continuity of fuel in the stand, from the ground to the tree crowns.

The spatial arrangement of silvicultural systems in a landscape and the time elapsed since harvesting affect fire risk and must be evaluated in the fire protection plan.

FOREST ENTOMOLOGY AND PATHOLOGY

Preliminary studies in the United States and Canada have investigated the use of alternative silvicultural systems to control or prevent insect or disease infestation.

In the United States, Amman *et al.* (1989) studied selection cutting as a means of controlling mountain pine beetle infestations and meeting non-timber values. The study made four observations:

- selection cutting of lodgepole pine stands significantly reduced lodgepole pine losses to mountain pine beetle;
- residual lodgepole pine trees responded with significant increases in diameter growth;
- regeneration after five years was adequate for overstory removal to proceed; and
- both logged and unlogged stands remained susceptible to mountain pine beetle infestation, based on information from diameter and vigour ratings of residual trees.

Shelterwoods in pure pine types in the Vernon Forest District of British Columbia have shown promise in mountain pine beetle control. The shelterwood stands experienced greatly reduced incidence of subsequent beetle attacks compared with neighbouring untreated stands. In addition, the residual trees responded to the reduced competition by achieving significant diameter release.

Research by Carlson and Wulf (1989) in the southern and central interior Douglas-fir and spruce-subalpine fir forest types indicates that silvicultural systems can reduce the forest and stand's susceptibility to western spruce budworm. Cutting should concentrate on leaving residual trees or stands that are vigorous and/or exhibit genetic resistance to western spruce budworm. By selecting the most heavily defoliated trees for removal and retaining the lightly or non-defoliated trees for seed trees, a more resistant stand can be created. Subsequent cone collection should favour those trees least susceptible to the budworm.

The threat of dwarf mistletoe, root rots, heart rots and stem infections strongly influence the choice of silvicultural system. Species notably affected by mistletoe are lodgepole pine, western hemlock, and interior Douglas-fir. In stands affected by dwarf mistletoe (*Arceuthobium spp.*) or root rot, clearcutting is recommended, followed by burning and planting — usually to an alternate species that is not affected by the pathogen. Parmeter (1978) found that dwarf mistletoe spreads more slowly through single-storied stands than through multi-layered stands, and that mixed-species stands had a lower incidence of dwarf mistletoe.

Schulting (1988) and Farnden *et al.* (1988) found the incidence of Indian paint fungus heart rot (*Echinodontium tinctorium*) to be acceptably low in interior stands of western hemlock less than 90 years of age. Where this pathogen is anticipated, even-aged silvicultural systems (e.g. clearcutting, seed tree or shelterwood) capable of producing a crop tree within this time frame are recommended.

Root rots (*Phellinus weirii, Armillaria ostoyae*) present a serious threat to coastal Douglas-fir, interior Douglas-fir and other species in the Southern Interior. Although these diseases may occur under all silvicultural systems, the most severe infections are often found with the selection system. Measures to isolate and minimize inoculum centres can be incorporated in all systems.

MECHANICAL DAMAGE TO CROP TREES AND SITE

Logging damage to residual stems, advance regeneration and young seedlings is difficult to avoid in any silvicultural system that relies on advance regeneration or residual growing stock to provide seed (i.e. shelterwood, seed tree and selection systems). Damage occurs during felling of the overstory, yarding (skidding) of the logs, site preparation and slash disposal. Once the overstory is removed, subsequent loss or damage to residual trees can occur through windthrow, breakage (wind and/or snow), sudden exposure to sunlight (sunscald), or diseases entering damaged stems. Camenzind (1989) estimated that damage can occur in 12-60% of stems, depending on the methods, skill and care of extraction.

Seidel and Cochran (1981) identified six steps to reduce damage to regeneration while harvesting under the shelterwood, partial cut and selection systems:

- ensure that the logger is well supervised so that the prescription and what is expected is clearly understood;
- clearly mark and clear skid trails prior to harvest;
- make use of directional falling and variable log length; trees should be felled into an opening in a herring bone pattern so that logs can be pulled into skid trails with least disturbance; trees laying at poor angles should be bucked into shorter logs instead of skidding full trees;
- skidders should stay on the trails and winch the logs prior to beginning their skid;
- skidding of unmerchantable timber to landings may be required to reduce the need to burn within the stand; and
- choose the season of harvest; frozen ground and a protective blanket of snow reduces soil compaction and damage to seedlings and the roots of residual trees.

Where species or terrain conditions preclude the protection of residual stems and regeneration throughout harvesting and management operations, the clearcutting system should be considered.

SOIL PRODUCTIVITY

Soils and soil productivity are also susceptible to damage during harvesting and management activities; their protection should be paramount in any silvicultural system. As harvesting takes place on more difficult terrain, where shallow soils and steep slopes predominate, planning and implementing protection measures become more critical.

Site and soil disturbance should not be confused with site degradation. Certain levels of site disturbance from logging and site preparation (burning or mechanical) are often desirable and planned to achieve successful forest regeneration. However, excessive levels of site disturbance can lead to site degradation when:

- loss of surface organic matter affects nutrient distribution;
- soil displacement exposes subsoils unsuitable for tree growth;
- excessive compaction leads to puddling;
- surface soil erosion leads to slope failure; and
- downslope movement of water and nutrients is interrupted.

The major impacts to soil and water quality result from road and landing construction, and from the skidding of logs. Site degradation can occur under any poorly planned or implemented silvicultural system.

The more roads built and more entries made into a stand, the greater the risk of damage to soil and regeneration. Clearcutting has the least amount of road construction (30% less than selection) and on-site traffic required per unit volume over time, while selection cutting requires the most.

NUTRIENTS

Martin and Harr (1988) found that logging of mature Douglas-fir in Western Oregon had little effect on nutrient output levels. The study was based on water samples taken since 1972 in a 130 year-old Douglas-fir forest. The amount of nutrient output via stream water was compared for three treatments: clearcut and broadcast burned, shelterwood cut and unlogged (control block). Both clearcut and shelterwood sites showed no increase in net loss of nutrients when compared to the control block.

Similar studies have been replicated in other watersheds in British Columbia, such as the Greater Victoria Watershed and Carnation Creek. The results are reproducible only where silvicultural systems are well planned and executed.

Appendix 3
SILVICULTURAL SYSTEMS IN THE UNITED STATES

While the application of silvicultural systems other than clearcutting has been relatively limited in British Columbia, some indication of the implications of other systems can be taken from their application on similar forest types in the United States.

WESTERN HEMLOCK - SITKA SPRUCE (Ruth and Harris, 1979)

This forest type, comprised mostly of western hemlock and Sitka spruce, includes western redcedar, yellow-cedar, and amabilis fir in British Columbia. This type occupies a narrow strip along the coastal mainland and the west coast of Vancouver Island, and the entire Queen Charlotte Islands in the hypermaritime subzones of the Coastal Western Hemlock zone.

Clearcutting, followed by natural regeneration, is the predominant system in use. The location, size and shape of cutblocks are carefully selected to conform to the landscape, and blocks are usually logged to windfirm boundaries. Where dwarf mistletoe is present, the complete removal of the overstory and destruction of the seedlings by fire is required.

Western hemlock and Sitka spruce lend themselves to shelterwood cutting since they are shade-tolerant. However, growth rates are slower under this system than when clearcut due to reduced light levels and overstocking of regeneration. The shelterwood system has been used predominantly where aesthetics or wildlife considerations are important and timber is secondary. Stands on wet sites are susceptible to blowdown.

The seed tree system is generally impractical in this forest type due to blowdown. Since both major species are prolific seed producers, natural regeneration is not difficult. Constraints associated with the application of the shelterwood system, such as overstocking and slow growth, also make the selection system impractical in this forest type.

COASTAL DOUGLAS-FIR (Williamson, 1973)

This is one of the world's most productive temperate forest types. It is common throughout much of coastal British Columbia - south of Kemano, and inland from the west coast of Vancouver Island in the drier and submontane subzones of the Coastal Western Hemlock zone and Coastal Douglas-fir zones. Associated species are grand fir, western hemlock, and western redcedar on the richer sites, and lodgepole pine on the poorer sites. The silvical characteristics and the regeneration requirements of coastal Douglas-fir dictate even-aged management and a complementary silvicultural system.

Clearcutting in approximately 20 hectare patches is the most commonly used system. Slash disposal is simpler than other systems, suitable seedbeds are readily created, and adequate light is provided for seedling development. Planting is often required due to natural regeneration failure on hot dry southern slopes, or on areas where frost is a hazard, and at times when seed source is inadequate. The present trend in these forest types is to reduce block size and delineate boundaries that blend in with the landscape, especially where visible from recreational routes. The seed tree system is seldom used in this forest type because windthrow has been a major problem.

Operational trials in the high Cascades have evaluated logging damage to regeneration when using the shelterwood system. While adequate regeneration was found to survive the removal of residual trees, the protection requirements of seedlings influenced the density of residual stocking. Fill-planting is often necessary, especially on steep ground where site preparation is difficult.

Uneven-aged management (i.e. selection system) was attempted in this type 47 years ago with unsatisfactory results. Slash disposal on the site was very difficult, resulting in extensive damage to standing trees and opening the residual stand to accelerated deterioration from insects, fungi, and the elements (especially wind). Not only was the mortality in the residual stand high as a result of logging, but there was also insufficient light for the regeneration of Douglas-fir, and stands were becoming converted to more shade tolerant and less desirable species. The conclusion from this experience was that uneven-aged management is not a good system to apply to coastal Douglas-fir.

TRUE FIR - HEMLOCK (Franklin, Emmingham and Jaszkowski, 1983)

This forest type is a diverse collection of montane and subalpine forests of the Cascade Range. In coastal B.C. it is found within the Coastal Western Hemlock and Mountain Hemlock zones. The zonal species group in the CWH zone is western hemlock-amabilis fir with associations of western redcedar, Douglas-fir and yellow-cedar. The zonal species group in the Mountain Hemlock zone is mountain hemlock - amabilis fir with associations of yellow-cedar and western hemlock.

True fir - hemlock forest types can be managed as either even- or uneven-aged, depending on the species composition and health of the stand. The choice of silvicultural system will depend on management objectives and the condition of the site. Steep slopes are common to these types, making non-clearcut systems difficult to implement. Other factors favouring the clearcutting system for this forest type include the susceptibility of these species to windthrow and dwarf mistletoe, and the mature/overmature structure of many stands.

Natural regeneration is easily achieved with these species, and advance regeneration is common. Sufficient advance regeneration of the true fir and hemlock species can be preserved through careful logging and slash disposal. Excessive site disturbance and/or broadcast burning make these sites generally difficult to reforest, due to the destruction of advance regeneration. Shelterwood systems and group selection can be employed, but they are not necessary to produce sufficient regeneration, and thinning will be required as a consequence of excessive regeneration.

MIXED PINE - FIR OF EASTERN OREGON AND WASHINGTON (Seidel, 1983)

The main species of this forest type consists of ponderosa pine, Douglas-fir and lodgepole pine. In British Columbia it corresponds to the Interior Douglas-fir zone, and includes western larch. In general, these pioneer species vary from moderately shade-tolerant to intolerant. The stand structure and species composition is extremely variable depending on site, logging history, insect and disease attacks and wildfire. The most important factor that affects the present composition of these forest types is wildfire. If timber production is the main objective, silvicultural systems which result in even-aged stands should be used in this forest type. The ecological requirements of the lodgepole pine and western larch components, the pressure to remove large volumes, and gradually increasing markets for smaller material indicate that even-aged management should be applied. The presence of dwarf mistletoe will often limit the choice to clearcutting.

ENGELMANN SPRUCE - SUBALPINE FIR (Schmidt, Wellner and Alexander, 1973)

This forest type corresponds to the Engelmann Spruce - Subalpine Fir zone of British Columbia. It exists in areas that, in general, are highly valued for timber productivity, water yields, scenic beauty, recreational potential and wildlife habitat. The spruce-fir forest types are frequently difficult to regenerate naturally or artificially at higher elevations, in the lower latitudes of their ranges, and on southerly exposures. The seed supply is modest, and small first-year seedlings are not resistant to heat and drought. If timber harvest is the objective, and the risks of windfall, bark beetle attack and disease are high, there is little choice but to clearcut and start a new stand. The openings should be small, to encourage natural regeneration, and slash disposal should be limited to what is necessary to provide an adequate seedbed. Planting is generally required due to poor seed crops. If insects,

disease and windthrow are not a concern, then the group seletion system or shelterwood systems can be used. The seed tree method is seldom used because spruce and fir are not windfirm, and seed crops are infrequent.

LODGEPOLE PINE (Lotan and Alexander, 1973)

This forest type is common in most of the Interior of B.C., especially in the Sub-Boreal Spruce zone and the Sub-Boreal Pine - Spruce zone. Insects, disease and fire play a vital role in lodgepole pine forest ecology, and many stands are opened up by a combination of mountain pine beetle and fire. Seed tree, shelterwood and selection systems are generally not applicable for several reasons:

- lodgepole pine is often not windfirm;
- partial cutting intensifies the spread of dwarf mistletoe, cankers and gall rust;
- slash disposal is difficult, and damage to residuals can occur; and
- lodgepole pine is shade-intolerant, and germination is sporadic.

Clearcutting is the most practical silvicultural system in this forest type, although there is inconclusive evidence that partial cutting in lodgepole pine stands helped control the spread of mountain pine beetle (McGregor and Cole, 1985; Amman *et al.*, 1989).